TECHNICAL REPORT

HISTORIC AMERICAN ENGINEERING RECORD (HAER) DOCUMENTATION
HISTORIC INDUSTRIAL LANDSCAPE DOCUMENTATION
ELIZABETH MINE

Strafford and Thetford, Vermont
CONTRACT NO. DACW33-03-M-0033

Principal Investigator
Suzanne Cherau

Historical Narrative Author
Matthew A. Kierstead

HAER Drawings
Dennis O'Brien

HAER Large-Format Black-and-White Photography
Robert Brewster

Aerial Landscape Color Photography
Charles Feil, Matthew A. Kierstead

Terrestrial Color Photography
Matthew A. Kierstead

Prepared for:
U.S. Army Corps of Engineers
New England District
696 Virginia Road
Concord, Massachusetts 01742-2751

Prepared by:
PAL
210 Lonsdale Avenue
Pawtucket, Rhode Island 02860

PAL Report No. 1237.04 November 2003

TABLE OF CONTENTS

CHAPTER **PAGE**

1. INTRODUCTION 1
Project History 1
Project Authority 3
Project Personnel 3
Acknowledgments 3

2. SITE DESCRIPTION 4

3. METHODOLOGY 6
HAER Documentation 6
Historical Narrative 6
Photographic Documentation 6
Documentary Drawings 6
HILD Documentation 7
Aerial Photographs 7
Terrestrial Photographs 7
Final Product Disposition 7

APPENDIX

A TECHNICAL REPORT ADDENDUM 11

CHAPTER ONE

INTRODUCTION

This report was prepared by PAL to accompany the Historic American Engineering Record (HAER) written, photographic and graphic documentation and the Historic Industrial Landscape Documentation (HILD) for the Elizabeth Mine Site in Strafford and Thetford, Vermont (Figure 1-1). The report includes a project history and information statement, methodology statement, and a description of the documentation products. The report also includes a summary of archival materials pertaining to the Elizabeth Mine located in regional repositories, and a list of repositories where the documentation packages will be archived.

PAL completed the HAER and HILD documentation of the World War II to 1958-era historic architectural, engineering and landscape resources at the Elizabeth Mine site under contract to the U.S. Army Corps of Engineers, New England District (ACOE-NAE). The ACOE-NAE is under contract with the Environmental Protection Agency (EPA) to perform a cleanup of the Elizabeth Mine, a Superfund site. The earthmoving activities related to the cleanup will have an adverse effect on the historical mining landscape. The historic and photographic documentation was performed as mitigation for the adverse effect.

Project History

The Elizabeth Mine has been determined to be a source of water contamination in the West Branch of the Ompompanoosuc River, a tributary of the Connecticut River. In June 2001 the Elizabeth Mine was designated as a National Priorities List (Superfund) site. As such, the EPA is responsible for coordinating the hazardous material cleanup of the site to protect human health and the environment.

Prior to the current HAER and HILD documentation projects, the site had been studied as part of the EPA's compliance with Section 106 of the National Historic Preservation Act and its implementing regulations, 36 CFR Part 800. The initial cultural resources study, titled *Statement of Limits, National Register Eligibility, and Potential Resources in the Proposed APE, Elizabeth Mine, South Strafford, Vermont,* was prepared by Hartgen Archaeological Associates, Inc. (Hartgen 2000). Supplemental reports, titled *Historical Context and Preliminary Resource Evaluation, Elizabeth Mine Site, South Strafford, Orange County, Vermont* (Kierstead 2001a), and an addendum report, titled *Addendum to Historical Context and Preliminary Resource Evaluation of the Elizabeth Mine, South Strafford, Orange County, Vermont* (Kierstead 2001b), were prepared by PAL under contract with Arthur D. Little, Inc. on behalf of the EPA. These studies resulted in the determination that the Elizabeth Mine Site is eligible for listing in the National Register of Historic Places by the EPA, in consultation with ACOE-NAE and the Vermont State Historic Preservation Office (VTSHPO).

In 2002 PAL completed *Historic/Archeological Mapping and Testing, Elizabeth Mine Site* under contract with the ACOE-NAE (Ford et al. 2003). The goal of these investigations was to locate, identify, photograph, map, and in some cases draw visible structural, artifactual, and landscape features associated with the Elizabeth Mine Site. Limited subsurface testing was also conducted to locate and identify any prehistoric period resources and a representative sample of belowground historic period resources.

The technical report is a scholarly document that not only fulfills the mandated legal requirements, but also serves as a scientific reference for future professional studies and as a framework for possible future interpretive programs.

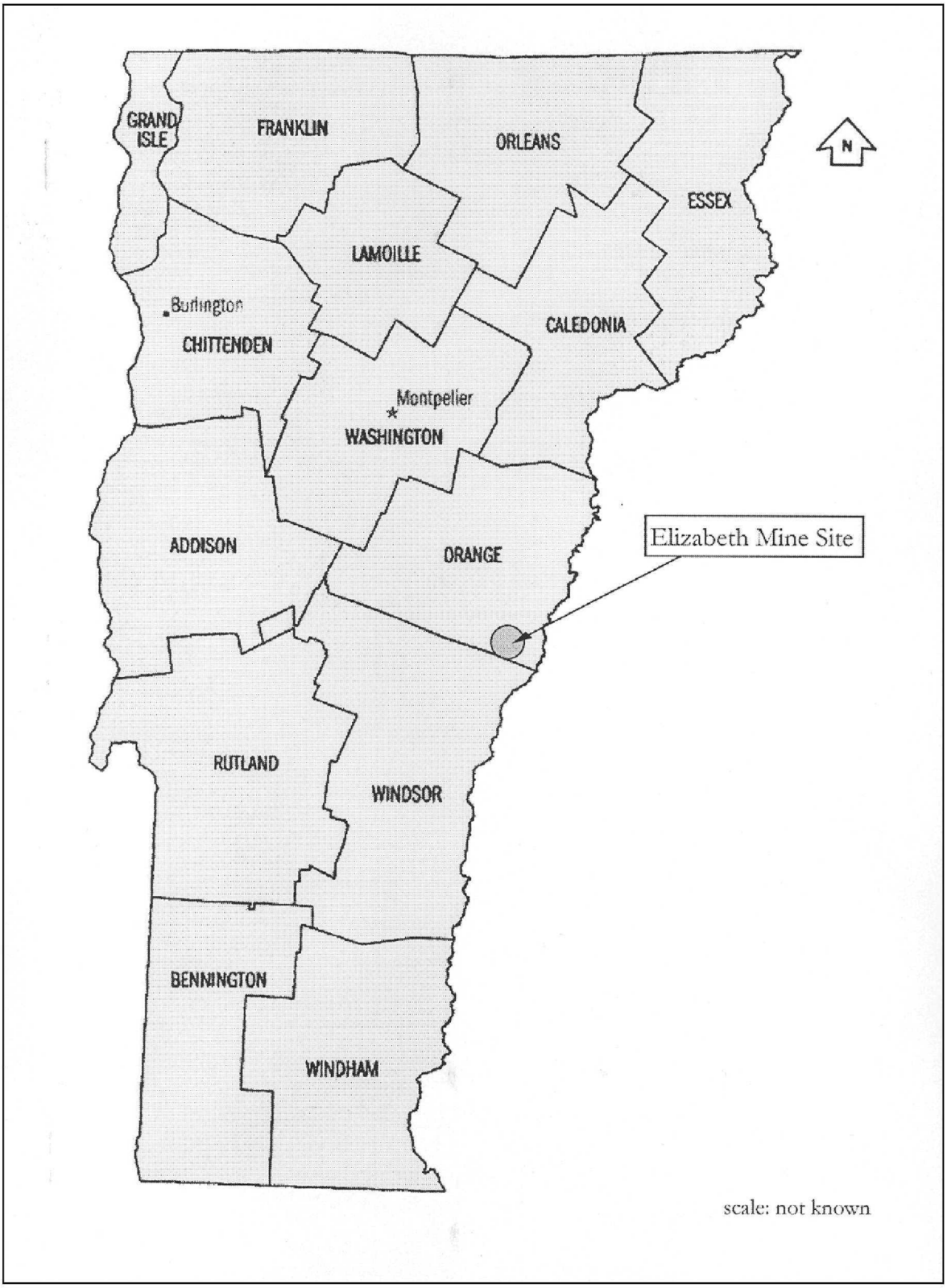


Figure 1-1. Map of Vermont, with the location of the Elizabeth Mine Site in Orange County.

Project Authority

The HAER and HILD documentations were conducted under the authority of the National Historic Preservation Act of 1966, (P.L. 89-665; 80 Stat. 915) as amended (16 U.S.C. 470 et seq.); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA–U.S. Code–Title 42); the Advisory Council on Historic Preservation, Protection of Historic Properties (36 CFR 800); the National Register of Historic Places, Nominations by States and Federal Agencies (36 CFR Part 60); and the Corps of Engineers Regulation ER 1105-2-50, Planning, Environmental Resources, Chapter 3, Historic Preservation.

All HAER and HILD documentation work was undertaken in accordance with the Secretary of the Interior's Standards and Guidelines for Archaeology and Historic Preservation (48 FR 44716, 1983), and the documentation standards and guidelines of the Historic American Buildings Survey/Historic American Engineering Record.

Project Personnel

The narrative and photographic documentation for the Elizabeth Mine Site were completed from March to August 2003. PAL staff involved in the project includes Deborah C. Cox (project manager) and Suzanne G. Cherau (principal investigator), who administered and coordinated the project with the ACOE-NAE archaeologist. Suzanne Cherau also assisted in the technical report structure and production. Matthew A. Kierstead (industrial historian) conducted the background research, measured and described the buildings, wrote the HAER narrative, conducted the Historic Industrial Landscape documentation terrestrial 35mm photography, assisted with the Historic Industrial Landscape documentation 35mm aerial and HAER large-format terrestrial photography, and assisted with the design of the HAER drawings. PAL subconsultants include Charles Feil of Views From Above, Scarborough, Maine, who conducted the aerial Historic Industrial Landscape documentation photography; Robert Brewster of Warren Jagger Photography, Providence Rhode Island, who conducted the large-format black-and-white HAER photography; and Dennis O'Brien of Mystic, Connecticut, who designed and executed the HAER ink-on-mylar drawings.

Acknowledgements

Matthew A. Kierstead, author of the HAER historical narrative, would like to acknowledge the assistance of mining historians Collamer M. Abbott of White River Junction, Vermont, and Johnny Johnsson of Finksburg, Maryland; Gwenda Smith, historian/curator of the Strafford Historical Society; and the staffs of the University of Vermont Bailey-Howe Library Special Collections Department, Burlington, Vermont; the Vermont State Library and Vermont State Archives, Montpelier, Vermont; and Vermont Historical Society Library, Barre, Vermont.

CHAPTER TWO

SITE DESCRIPTION

The Elizabeth Mine was established in the early nineteenth century and operated until the mid-twentieth century. It lies approximately one mile south of the West Branch of the Ompompanoosuc River, in the rugged uplands of east-central Vermont. This section of Orange County hosted mining activity in the approximately 20-mile-long Copper Belt, and by the late nineteenth century was the location of several other mining operations, including the Ely Mine in Vershire (VT-OR-14) and Pike Hill Mines (Eureka and Union) (VT-OR-27) in the town of Corinth. Today, Elizabeth Mine contains major mining landscape features, numerous standing structures, and the aboveground and buried remains of structures and features related to several periods of mining operations at the site. There are also a number of non-mining historic period farmstead sites within the approximately 800-acre mine site.

The majority of the Elizabeth Mine Site is located in Orange County, Vermont, approximately 12 miles north of White River Junction and approximately 10 miles west of the Connecticut River. The roughly 800-acre site is located southeast of the village of South Strafford in the southeastern corner of the town of Strafford, with an eastern portion in Thetford and small portions at its southern extremity in Sharon and Norwich, which are located in Windsor County. The site is located within the drainages of Copperas Brook and Lord Brook, which flow north and east to the West Branch of the Ompompanoosuc River, a major tributary of the Connecticut River located approximately 1 mile north of the site.

The Elizabeth Mine Site is roughly diamond-shaped, stretching from the Air Shaft and Electrical Substation on the North Bank of the Ompompanoosuc River in the Rte 132-Furnace Flat vicinity in Strafford, approximately 2 miles south to the waste rock and prospect pits south of the Old South Mine in the extreme northeast corner of the town of Sharon; and from the Sargent Brook smelter site at the west foot of Copperas Hill in Strafford approximately 1 mile east to the east tip of Tailings Pile 1 at the west foot of Gove Hill in Thetford. The core of the mine site that includes the mid-twentieth-century resources in this documentation is located in the east-central part of the diamond-shaped area in the Copperas Brook valley on the east flank of Copperas Hill, west of Gove Hill, approximately 1¾-miles southeast of the intersection of Vermont Route 132 and Mine Road in the village of South Strafford.

The HAER documentation focuses on the 1942–1958 resources including the clusters of buildings on Mine Road, and the surrounding shafts and adits where the orebody was accessed, open cuts where ore was mined, waste piles where rock and mill tailings were deposited, and connecting transportation and utility routes. The nerve center of period operations was the complex of World War II-era buildings approximately 1¾-miles southeast of the village of South Strafford on Mine Road. The core of this complex consists of two clusters of wood frame buildings and a variety of structures arranged on a series of man-made terraces on the eastward-sloping east toe of Copperas Hill, east of Mine Road. The north-south surface trend of the linear orebody is located approximately ¼ mile to the west of the mine buildings, with the orebody plunging east and under them. Underground access to the orebody was via the 1898 Adit and 1948 Adit (horizontal tunnels), which began at the south and north ends of the building complex, respectively, and extended underground west to intersect the orebody at the 300 ft level.

The 1948 Shaft was located above the buildings on the hillside approximately 375 ft west of the 1948 Adit, and intersected the latter working at the 300 ft level and descended to the 975 ft level. The mine also worked surface exposures of the orebody in a pair of north-south oriented linear open cuts located uphill to the southwest. The North Open Cut, a previously mined rock trench approximately 1,000 ft long, is located approximately 2,000 ft southwest of the core mine buildings, west of the Copperas Works Site, the remains of a nineteenth-century iron sulfate manufactory. A pile of 1880s mine waste rock north

of this cut was removed for milling for its copper content in 1949–1950. The South Open Cut, located approximately 500 ft south of the North Open Cut, is an approximately 1,600 ft long rock trench that was excavated in 1950–1953. A network of roads connects these ore sources with the mine buildings. Ore milling left Tailings Pile 1 and Tailings Pile 2, large piles of sandy waste, east and down slope of the mine buildings in the Copperas Brook valley. These tailings piles occupy a wedge-shaped, north-south oriented area approximately 2,000 ft long that begins approximately 300 ft east of the mine buildings. Tailings Pile 1 is the larger, lower of the two and has a 150 ft high, 1,400 ft long north slope. Tailings Pile 2 is smaller and located at the south end of Tailings Pile 1. This core area of buildings, mine workings, and waste piles is surrounded by additional historic mining buildings, structures, and landscape features.

Out of approximately 30 buildings and structures built in the World War II building campaign, only 14 remain intact and standing. The surviving buildings include ore processing structures and support/service facilities. These buildings were constructed to wartime emergency standards and of functional design. Most were constructed of 2-x-6-inch studs placed on 18-inch centers with horizontal stops every 2 feet. These stops formed sealed air compartments for insulation. The frame corners are stabilized with diagonal bracing. The inside and outside of exterior walls were sheathed with panels of "Gyplap," a U.S. Gypsum Company gypsum construction board. The exteriors were sheathed in textured, buff-colored asphalt panels with a common bond brick pattern. Roofs have overhanging eaves with exposed rafter tails and are typically sheathed with black asphalt shingles. Windows are typically six over six, double-hung, wood sash units. Roof trusses are commonly spaced at 2-foot intervals. Reinforced concrete foundations are typically 8 inches thick and were cast in forms using 6-inch wide planks. Many of these buildings share these construction materials and details.

CHAPTER THREE

METHODOLOGY

This chapter outlines the tasks undertaken to complete the HAER-level documentation of the World War II-era buildings and associated landscape elements, and the HILD documentation of major mining landscape elements at the Elizabeth Mine Site. These tasks included two separate documentation packages: a standard HAER documentation including a historical narrative, ink-on-mylar drawings, and large-format black-and-white photographs of the 1942–1958 buildings and landscapes; and a 35mm color transparency Historic Industrial Landscape documentation of all major landscapes from all periods of operation.

HAER Documentation

Historical Narrative

The historical narrative concentrates on the 1942 – 1958 period of mine operations. The narrative incorporates additional background research and field investigations that complement existing information gathered and presented in previous reports. Background research for the narrative focused on collecting additional information about general activities during the 1942–1958 period, as well as information on underground mining practice, progress, and equipment; materials handling; and ore processing methods, equipment, layout, and changes. This additional research included examination of archival materials belonging to the Strafford Historical Society, period technical and industry literature, consultation with mining engineers and historians, and oral interviews with former Elizabeth Mine employees. The narrative explains how the period's buildings and landscape (North and South Open Cuts, Tailings Piles 1 and 2) reflect industrial processes at the Elizabeth Mine. The narrative includes descriptions of the World War II-era buildings and additional historic views of mine operations and landscape during the World War II to 1958 period. The narrative also includes brief synopses of activities at the Ely and Pike Hill mines that also operated in Orange County.

Photographic Documentation

The standard HAER-level photographic documentation consists of 66 traditional large format (4" X 5" [4 X 5]) black-and-white photographs of the standing World War II-era structures, including the upper tier of administrative, maintenance and operations buildings; the 1898 Adit and mine car rail line and trestle/bridge; the lower tier of ore processing buildings; and the Ompompanoosuc River pump house. This documentation also includes representative views of the landscapes associated with World War II-era ore extraction and waste deposition, including the North and South Open Cuts, Tailings Piles 1, 2 and 3, and the 1948 shaft site. The documentation does not include photographic copies of historic images depicting mining processes.

All photographs were taken using a Sinar F 4 X 5 large format field camera. The final product consists of two sets of archivally washed black-and-white negatives and five sets of archivally washed black-and-white fiber base contact prints. An Index to Photographs and a Key to Photographs accompanies the prints.

Documentary Drawings

This series of four standard HAER format drawings records the locations and relationships of the historic World War II-era mining buildings, mine openings, and associated proximate resources including tailings

piles, roadways, and utilities, and shows the ore processing system and steps. The drawings show the Elizabeth Mine site in increasing detail and scale. The first drawing (cover sheet) shows the overall Elizabeth Mine landscape in the valleys of Copperas, Lord and Sargent brooks and the West Branch of the Ompompanoosuc River, and a section showing underground mining progress. It includes sidebars containing a brief mine history and project information. The second drawing shows the core World War II-era mine buildings and explains their functions. The third drawing is an isometric translucent block diagram showing the flow of ore from the underground workings and through the ore concentrating process buildings, including information about underground mining methods. The fourth drawing documents the ore beneficiation process using a flow chart incorporating graphic representations of the types of machinery used.

The project historian provided the artist with historic maps, photographs, images, and text relevant to each drawing as well as sketches of proposed drawing layouts. The drawings were further developed and finalized through a series of scheduled charettes and reviews. The drawings were created digitally. The final original drawings are hand-drawn in ink-on-mylar sheets. The drawings were completed to HAER standards for size, content, materials, line weights, typeface, and other formal details.

The final product consists of one set of four ink-on-mylar original drawings from which multiple copies in blackline on bond were made.

HILD Documentation

This documentation was divided between aerial and terrestrial (ground) photography of the major, large-scale historic industrial landscape features including the North and South Open Cuts, and Tailings Piles 1, 2, and 3. The terrestrial documentation also included the Old South Mine area.

Aerial Photographs

Aerial Historic Industrial Landscape photography was conducted from a light plane. All aerial color photographs were taken with a 35mm camera. The final product consists of 25 aerial 35mm color transparencies (slides). Views include the overall mine site as well as details of specific landscape features.

Terrestrial Photographs

Terrestrial Historic Industrial Landscape photography was taken with a 35mm camera. The final product consists of 59, 35mm color transparencies (slides). The views include overviews and detail views of all major industrial landscape features.

The aerial and terrestrial photographic landscape documentation includes a Project Information Sheet, an Index to Photographs, and a Key to Photographs based on existing project site mapping.

Final Product Disposition

The Vermont History Center Library, Barre, Vermont; and the University of Vermont Bailey-Howe Library Special Collections, Burlington, Vermont, each received:

- one individually sleeved set of 66 large-format 4 X 5 black-and-white HAER documentation negatives;

- one set of 66 large-format 4 X 5 black-and-white HAER documentation contact prints with photo index and key maps;
- one set of four blackline-on-bond HAER documentation drawings;
- one unbound HAER documentation narrative history;
- one set of 84, 35mm Historic Industrial Landscape documentation color slides with photo index and key maps;
- one set of compact disks containing all of the imagery described in the bulleted items above, plus the text and images from the PAL Elizabeth Mine reports including PAL 2000 (Historical Context), 2001 (Addendum), 2003 (Historic and Archaeological Investigations), and 2003 (HAER/Historic Industrial Landscape) documentations and Technical Report in Adobe Acrobat reader format.

The Vermont Division for Historic Preservation (VT State Historic Preservation Office), Montpelier, Vermont received:

- one set of 66 large-format 4 X 5 black-and-white HAER documentation contact prints with photo index and key maps;
- one set of four blackline-on-bond HAER documentation drawings;
- one unbound HAER documentation narrative history;
- one set of 84, 35mm Historic Industrial Landscape documentation color slides with photo index and key maps;
- one set of compact disks containing all of the bulleted items above, plus the text and images from the PAL Elizabeth Mine reports including PAL 2000 (Historical Context), 2001 (Addendum), 2003 (Historic and Archaeological Investigations), and 2003 (HAER/Historic Industrial Landscape) documentations and Technical Report in Adobe Acrobat reader format.

The Strafford Historical Society, Strafford, Vermont, received:

- one set of 66 large-format 4 X 5 black-and-white HAER documentation contact prints with photo index and key maps;
- one set of four blackline-on-bond HAER documentation drawings;
- one unbound HAER documentation narrative history;
- one set of compact disks containing scanned images of the 84, 35mm Historic Industrial Landscape documentation color slide images with photo index and key maps, plus all of the bulleted items listed above, and also digital format text and images from all PAL Elizabeth Mine reports including: PAL 2000 (Historical Context), 2001 (Addendum), 2003 (Historic and Archaeological Investigations), and 2003 (HAER/Historic Industrial Landscape) documentations and Technical Report in Adobe Acrobat reader format.

ACOE-NAE received, for their records:

- one set of photocopies of all large-format 4 X 5 black-and-white HAER documentation contact prints;

- one set of four blackline-on-bond HAER documentation drawings;

- fifteen bound copies and one unbound camera-ready original of the HAER documentation narrative history;

- fifteen bound copies and one unbound camera-ready original of the (HAER/Historic Industrial Landscape documentations Technical Report;

- one set of CDs containing digital scans of all large-format 4 X 5 black-and-white HAER documentation contact prints; digital scans of the 84, 35mm Historic Industrial Landscape documentation color slides; digital scans of the four HAER documentation drawings; and digital format text and images from all PAL Elizabeth Mine reports including: PAL 2000 (Historical Context), 2001 (Addendum), 2003 (Historic and Archaeological Investigations), and 2003 (HAER/Historic Industrial Landscape) documentations and Technical Report in Adobe Acrobat reader format. *The ACOE-NAE report disks will also include the 2003 (HAER/Historic Industrial Landscape) documentations and Technical Report in Word format.*

PAL retained the four original HAER ink-on-mylar drawings, one non-archival set of large-format HAER black-and-white contact prints, and one set of the 35mm Historic Industrial Landscape documentation color slides (aerial views only).

APPENDIX A

TECHNICAL REPORT ADDENDUM

TECHNICAL REPORT ADDENDUM

ORANGE COUNTY, VERMONT, COPPER MINE HISTORIC ARCHIVES SUMMARY

University of Vermont

The University of Vermont Bailey–Howe Library Special Collections Department contains several record groups pertaining to the Elizabeth Mine at South Strafford, the Ely Mine at Vershire, and the Pike Hill mines at Corinth. The most important collections are the Collamer Abbott Papers, the Records of the Vermont Copper Company, and the Westinghouse Papers. Several other collections include material associated with the mines, including the Governor Roswell Farnham, Governor Stanley C. Wilson, and Nash papers. Those materials were not examined for this report, although Collamer Abbott's transcribed notes from the Nash papers include revealing information about the operations of the copperas and copper works at the Elizabeth Mine in the mid-nineteenth century.

Collamer M. Abbott Papers

Collamer Abbott (1919–) was born in Wilder, VT, just a few miles from the Vermont copper mines. The history of the mines was a major subject of interest for Abbott, who spent considerable time and personal resources investigating their landscapes and researching their history. During the mid-1960s, Abbott synthesized much of his work in two manuscripts that remain unpublished and are now part of the UVM materials. "Appalachian Copper: Red Metal Mining in the Eastern United States," (1962, 397pp) provides an overview of the subject, including sections on the colonial era, the early formation of the industry, the nineteenth century in the North and South, the early twentieth century, the financiers, geologists, engineers, technology, the influence of Cornish miners, and life at the mines. The manuscript includes a 48-page bibliography. "Green Mountain Copper" (1964, 475pp) focuses on copper mining in Orange County, Vermont, and includes sections on the Elizabeth, Ely and Pike Hill mines. An abbreviated (36pp) version of this manuscript, "Green Mountain Copper: Vermont's Red Metal" was published in 1973. A shorter manuscript, "The Ely Mine: A Case Study," focuses on the nineteenth-century "boom" years at the Ely Mine. Abbott also published numerous shorter articles about various Eastern U.S. copper mining subjects in a variety of economic and historical journals. The Collamer Abbott Papers include numerous typewritten versions of these manuscripts and articles. Abbott's research notebooks and cross-referenced index card files are included in the collection. The collection also includes roughly 4,000 photographs of the Orange County mines and surrounding communities. Most of these are still in negative format, however, many of the best ones have been printed and are included in the collection. The photograph collection is also notable for its coverage of the Ely Mine workings and village, including an extensive photograph collection.

The Collamer Abbott Collection consists of eight cartons of papers, one carton of card files, one carton of notebooks, one box of oversize maps, two boxes of printed photographs, five boxes of glass plate negatives and one box of plastic negatives. The variety of material in this collection is too great to describe here. A finding aid was prepared for the papers in December 1980 by Mary Gelinas and is available online at the University of Vermont's website (http://bailey.uvm.edu:6336/dynaweb /findingaids/abbott).

Vermont Copper Company Collection

The Records of the Vermont Copper Company consist of four cartons and one box of papers, 10 bound volumes, and 16 oversize maps. The collection includes material about the unrelated nineteenth-century company of the same name that owned and operated the Ely Mine in Vershire. Mary Gelinas prepared a finding aid for the papers in November 1980.

The papers consist mainly of business records of the Vermont Copper Company's 1942–1958 period of formation, growth, and demise at the Elizabeth Mine. The papers are divided into series by correspondence, financial, legal, and stockholder information. There are also folders for general information and printed matter. The maps are mostly of the Ely Mine, including 1943 maps of the underground workings and maps from 1900 of a proposed railroad route from Ely Station on the Connecticut River to the mine.

Westinghouse Papers

The Westinghouse Papers consist of records pertaining to the ca. 1900 1905 George Westinghouse operations at the Ely Mine. Although they were not closely examined for this report, they complement the Westinghouse materials recently acquired by the Vermont Historical Society (see below) and shed light on early-twentieth-century Ely smelting activities.

Additional Repositories

Vermont State Archives, Montpelier

The Vermont State Archives contain records pertaining to state government involvement in the Orange County copper mines, including articles of incorporation, nineteenth- and twentieth-century state geological survey reports, and World War I and World War II strategic production materials. The papers of Governor William H. Wills (1941–1945) include sorted materials on copper mines and his role as state defense mines coordinator.

Vermont State Library, Montpelier, Vermont

The Vermont State Library contains information pertaining to the Orange County mines and host communities including microfilmed census data for population, agriculture, and industry for the late eighteenth, nineteenth and twentieth centuries. It also contains local, county and state histories and gazetteers, and bound copies of state agricultural and geological surveys and reports.

Vermont Historical Society Library, Barre, Vermont

The Vermont Historical Society Library includes a variety of scattered information about the Orange County copper mines. Although there is not a great volume of material, notable items such as Isaac Tyson, Jr.'s 1833 Elizabeth Mine journal indicate the potential value of individual items at this repository. The recently acquired Copperfield Mine Company Collection, which contains information associated with George Westinghouse's ca. 1900–1905 activities at the Ely Mine, contains information important to understanding Ely smelting activities at that time. The Ely Mine photograph collection includes a variety of views of the mining landscape and village, as well as photos of the smelting furnaces.

Strafford Historical Society, Strafford, Vermont

The Strafford Historical Society has compiled an extensive bibliography and collection of printed matter associated with the Elizabeth Mine. Their holdings include a large collection of photographs and slides of the late-nineteenth-century and twentieth-century Elizabeth Mine landscape and buildings.

United States Geological Survey, Reston, Virginia

The United States Geological Survey is temporarily holding a large collection of original Vermont Copper Company and Dartmouth College geological maps of the underground workings at the Elizabeth Mine for use in their studies of Appalachian sulfide ore deposits. These studies included reorganization and documentation of surviving drill cores now stored in the Washhouse at the Elizabeth Mine.

Elizabeth Mine Study Group, Thetford, Vermont

The Elizabeth Mine Study Group, a local organization, has acquired additional materials from sources including Dartmouth College and from former mine workers.

HISTORIC INDUSTRIAL LANDSCAPE DOCUMENTATION
AERIAL AND TERRESTRIAL 35MM COLOR TRANSPARENCIES
ELIZABETH MINE, STRAFFORD AND THETFORD, VT

ELIZABETH MINE

Strafford and Thetford, Vermont

CONTRACT NO. DACW33-03-M-0033

Principal Investigator
Suzanne Cherau

Aerial Landscape Color Photography
Charles Feil, Matthew A. Kierstead

Terrestrial Color Photography
Matthew A. Kierstead

Prepared for:
U.S. Army Corps of Engineers
New England District
696 Virginia Road
Concord, Massachusetts 01742-2751

Prepared by:
PAL
210 Lonsdale Avenue
Pawtucket, Rhode Island 02860

PAL Report No. 1237.04 November 2003

HISTORIC INDUSTRIAL LANDSCAPE DOCUMENTATION

INDEX TO PHOTOGRAPHS

Elizabeth Mine
Mine Road,
(1.75 miles southeast
of the intersection of
Vermont Route 132
and Mine Road in the
village of South Strafford)
Orange County
Vermont

Aerial Photographs (Photographs 1–25)

Photographers: Charles Feil, Views from Above, Scarborough, ME; Matthew A. Kierstead, PAL, Pawtucket, RI. April 2003

1. Overview looking west with Copperas Works Area at center and Tailings Piles 1 and 2 at right

2. Overview looking west with Copperas Works Area at upper right and Tailings Piles 1 and 2 at lower right

3. Overview looking southwest with North Open Cut/Copperas Works Area at top and Tailings Piles 1 and 2 at bottom

4. Overview looking south with Tailings Piles 1 and 2 at bottom and North Open Cut/Copperas Works Area at upper right

5. Overview looking northeast with South Open Cut in foreground, Copperas Works Area at upper left, and Tailings Piles 1 and 2 at upper right

6. Overview looking northeast with Copperas Works Area at bottom and Tailings Piles 1 and 2 in background above

7. Overview looking northwest with Tailings Pile 2 at left and Tailings Pile 1 at center

8. View looking northwest with South Open Cut at lower left and North Open Cut at upper right

9. View looking northwest with South Open Cut in foreground and North Open Cut/Copperas Works Area in background above

10. View looking north with South Open Cut in foreground and North Open Cut/Copperas Works Area in background above

11. View looking south with North Open Cut/Copperas Works Area in foreground and South Open Cut in background above

12. Copperas Works Area looking west with Mine Road in foreground at bottom and North Open Cut at top of open area

13. Copperas Works Area looking northwest

14. North Open Cut and Copperas Works Area looking southwest

15. North Open Cut and Copperas Works Area looking west

16. North Open Cut and Copperas Works Area looking northwest

17. Tailings Pile 1 looking south with Tailings Pile 2 at upper right and Mine Road at right edge

18. Tailings Pile 1 looking southeast with Mine Road in foreground at bottom and Tailings Pile 2 at right edge

19. Tailings Pile 1 looking northeast with Tailings Pile 2 at center

20. Tailings Pile 1 looking west with Tailings Pile 2 at left edge

21. Tailings Pile 1 looking southwest with Tailings Pile 2 at center and Copperas Works Area/North Open Cut in background at top left

22. Tailings Pile 2 looking southwest with World War II mine buildings at right

23. Tailings Pile 2 looking south with World War II mine buildings at right

24. World War II mine buildings, upper tier, looking southwest showing from left to right: Change House, 1898 Adit, collapsed Compressor Building, Machine Shop/Workshop, Office/Warehouse Building, and "Copper Castle" at upper right

25. World War II mine buildings, lower tier, looking southwest showing from left to right: Garage, Heating Plant, Concentrating Mill, and Thickener/Filter Building, with Mine Car Bridge at top

Terrestrial Photographs (Photographs 26–84)

Photographer: Matthew A. Kierstead, PAL, Pawtucket, RI. April–June 2003

26. Tailings Pile 1 looking west from east end of north toe

27. Tailings Pile 1 looking west from north lip

28. Tailings Pile 1 looking east from starter dam at middle of north toe

29. Tailings Pile 1 looking south from northwest corner

30. Tailings Pile 1 looking northeast at northwest corner

31. Tailings Pile 1 looking east from northwest corner

32. Tailings Pile1 looking northeast at west slope

33. World War II ore processing buildings and west slope of Tailings Pile 1 looking north from Tailings Pile 2

34. Top of Tailings Pile 1 looking northeast from Tailings Pile 2

35. Top of Tailings Pile 1 looking north from east edge

36. Top of Tailings Pile 1 looking north across Copperas Brook

37. Top of Tailings Pile 1 looking north across pond

38. World War II ore processing buildings looking southwest from west lip of Tailings Pile 1 showing from left to right: Garage, Heating Plant, Concentrating Mill, and Thickener/Filter Building

39. World War II ore processing buildings looking northwest from west lip of Tailings Pile 1 showing from left to right: Garage, Concentrating Mill, Heating Plant, and Thickener/Filter Building

40. Tailings Pile 2 looking southeast from north tip

41. Northeast face of Tailings Pile 2 looking west from top of Tailings Pile 1

42. Northeast face of Tailings Pile 2 looking west across Copperas Brook from top of Tailings Pile 1

43. Tailings Pile 2 looking west from east edge of Tailings Pile 1

44. Washout gully in Tailings Pile 2 looking northwest from east edge of Tailings Pile 2

45. Washout gully in Tailings Pile 2 looking north across top of Tailings Pile 1

46. Washout gully in Tailings Pile 2 looking northwest

47. Tailings Pile 2 looking northwest across lip

48. Washout gully in Tailings Pile 2 looking southwest showing collapsed concrete pipe culvert for Copperas Brook and tailings water decant system

49. North Open Cut looking north from midpoint with 1880s Tyson mining area in background

50. North Open Cut looking north from midpoint with Copperas Works Area at right

51. North Open cut looking north showing north wall openings and 180s Tyson mining area in background

52. North Open Cut looking north showing north wall openings

53. North Open Cut looking south

54. Copperas Works Area looking southwest from Copperas Road

55. Copperas Works Area looking north from heap leaching beds at middle of hill

56. Copperas Works Area looking east from heap leaching beds at middle of hill

57. Copperas Works Area looking northwest from heap leaching beds showing remains of timber leach pad cribbing

58. Copperas Works Area looking west from south edge below Copperas Road

59. Copperas Works Area looking northwest from south edge below Copperas Road

60. Copperas Works Area looking north from south edge below Copperas Road

61. Copperas Works Area looking northwest from south edge below Copperas Road showing oxidized mining waste rock and roasted and leached ore piles

62. Copperas Works Area looking north from south edge below Copperas Road showing oxidized mining waste rock and roasted and leached ore piles

63. Copperas Works Area looking northeast in area below Copperas Road showing oxidized mining waste rock at left and roasted and leached ore piles at center and right

64. Copperas Works Area looking north in area below Copperas Road showing roasted and leached ore piles at left and center and oxidized mining waste rock at right

65. Copperas Works Area looking north in area below Copperas Road showing roasted and leached ore piles in foreground and oxidized mining waste rock in right background

66. Copperas Works Area looking west in area below Copperas Road showing roasted and leached ore piles at center and brick debris at lower right

67. Copperas Works Area looking west in area below Copperas Road showing roasted and leached ore piles at center with remains of timber support cribbing

68. Copperas Works Area looking southwest in area below Copperas Road showing roasted and leached ore piles in left background and oxidized mining waste rock at center and right

69. South Open Cut looking south from north end showing rough footwall at right

70. South Open Cut looking south from north end showing recently collapsed area at center

71. South Open Cut looking south from north end showing smooth hanging wall at left

72. South Open Cut looking northeast from west side near north end showing high part of hanging wall

73. South Open Cut looking northeast from west side south of north end looking along hanging wall

74. South Open Cut looking south from west side south of collapsed area near north end

75. South Open Cut looking north from west side at approximate midpoint

76. South Open Cut looking north from west side juts north of crosscut

77. South Open Cut looking east through crosscut from west side

78. South Open Cut looking southeast from west side showing crosscut at left and south continuation of cut at right

79. South Open Cut looking north from west side south of crosscut

80. South Open Cut looking north from east side near south end

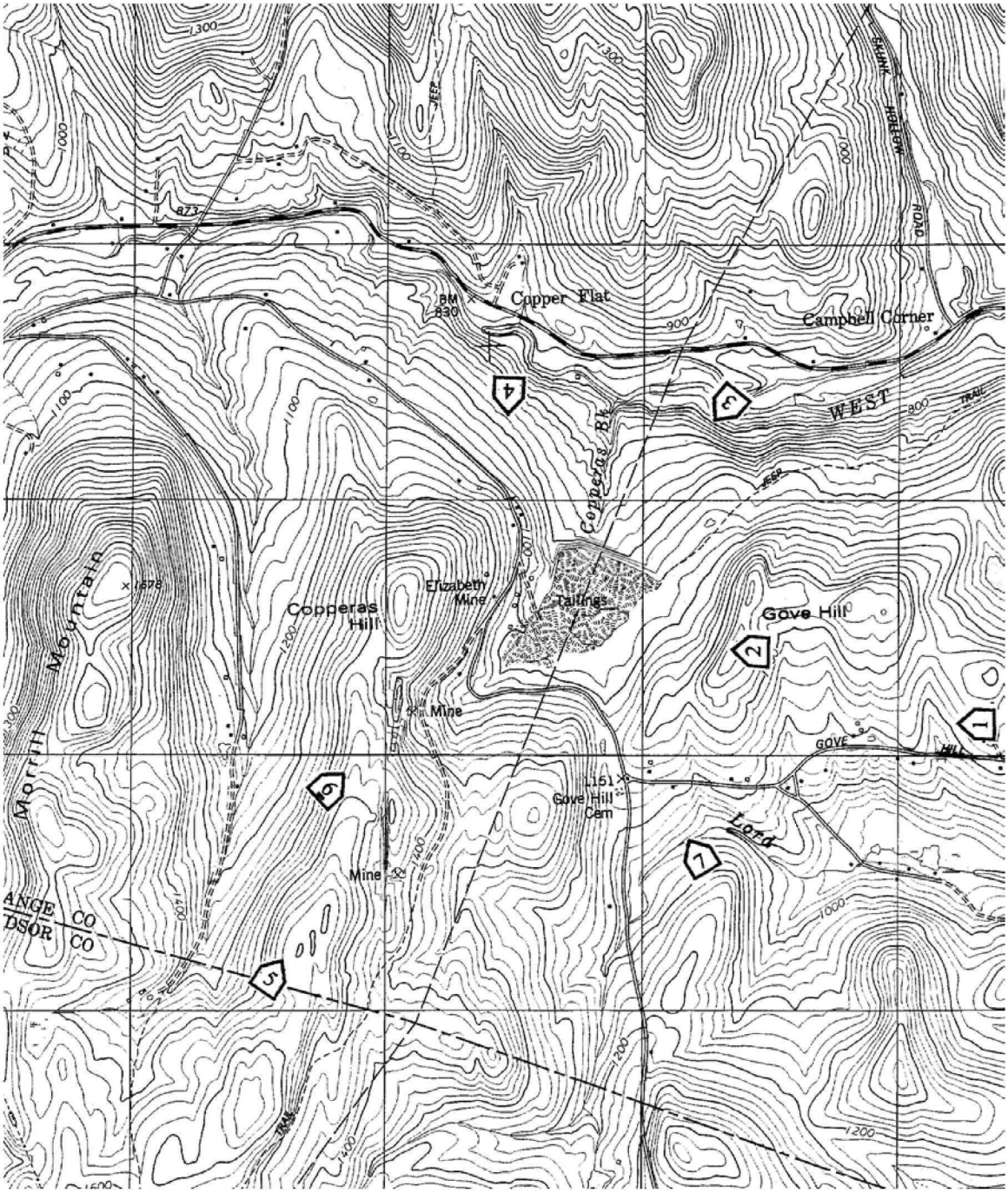
81. South Open Cut looking north from south end

82. Old South Mine looking east showing room-and-pillar mining remains

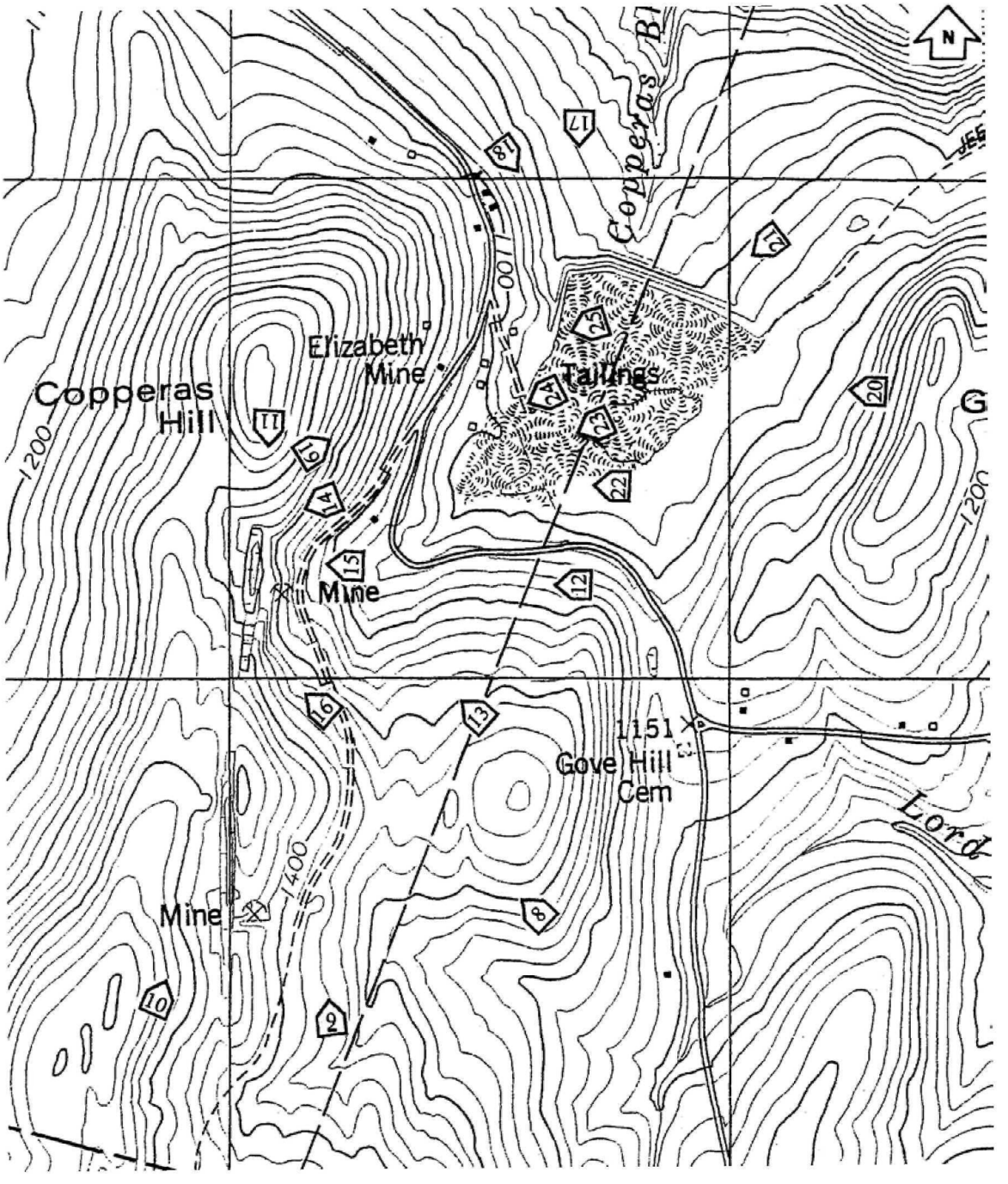
83. Old South Mine looking north

84. Old South Mine looking north to flooded trench

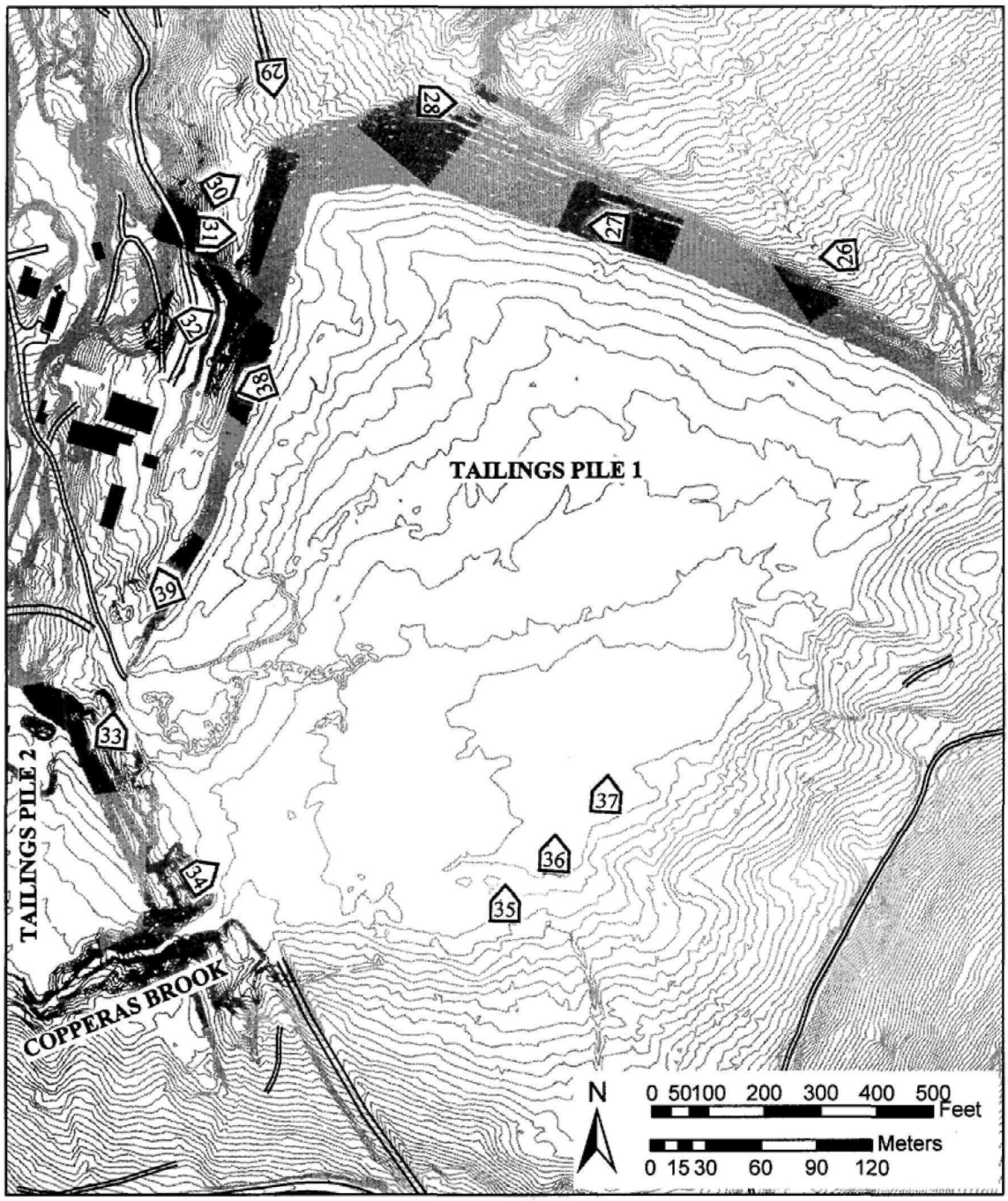
Aerial Overviews



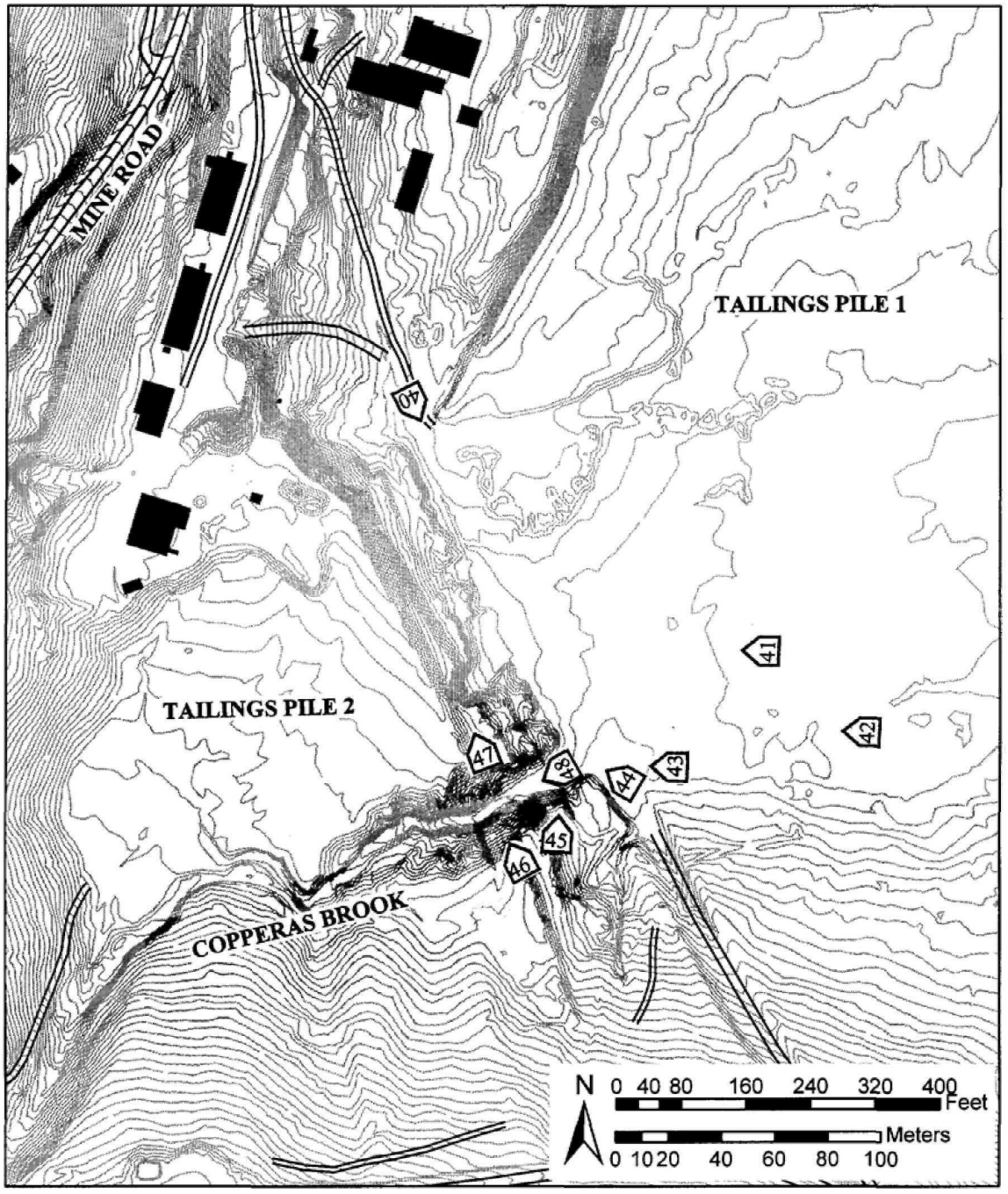
Aerial Details



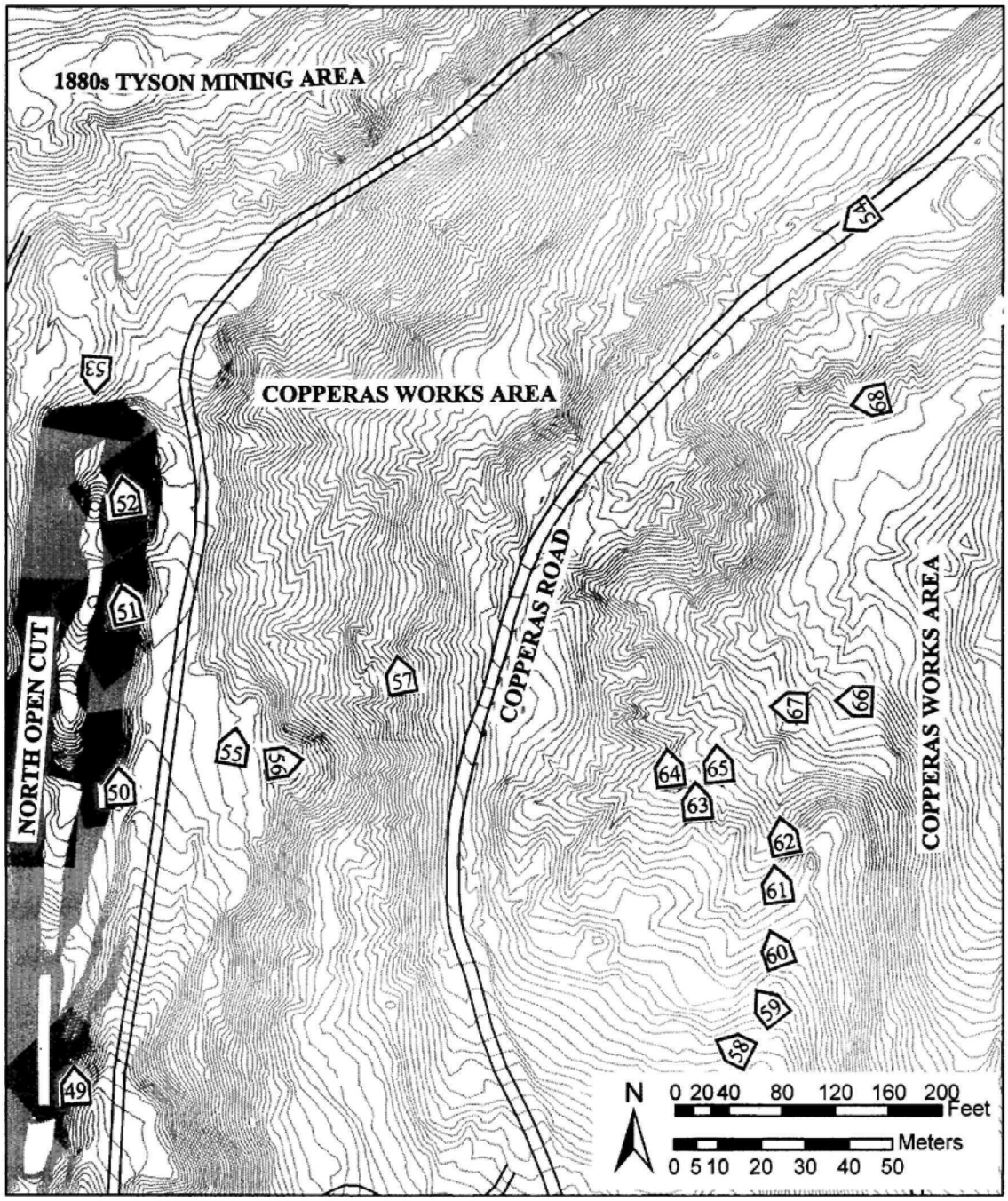
Tailings Pile 1 and World War II Buildings



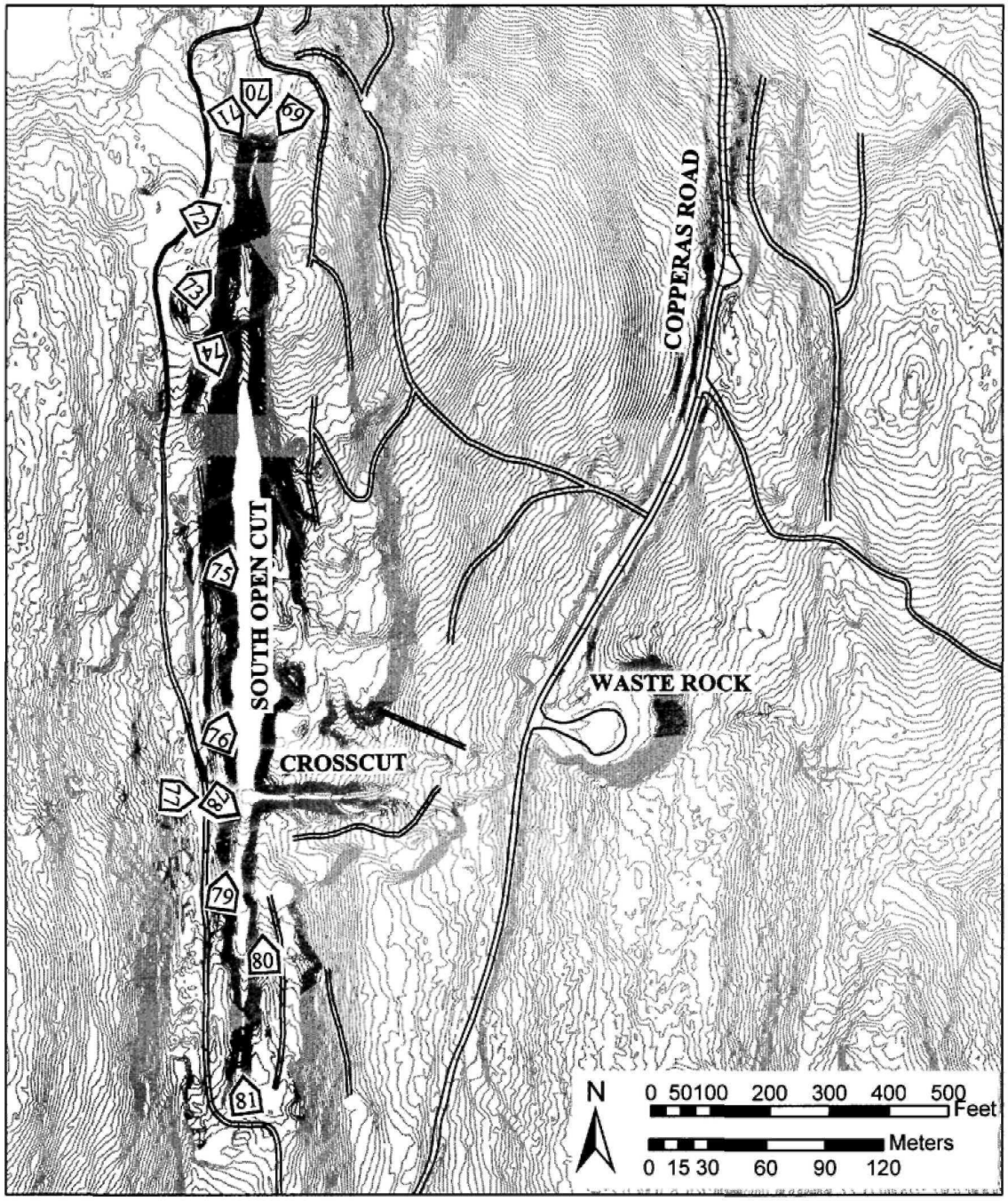
Tailings Pile 2



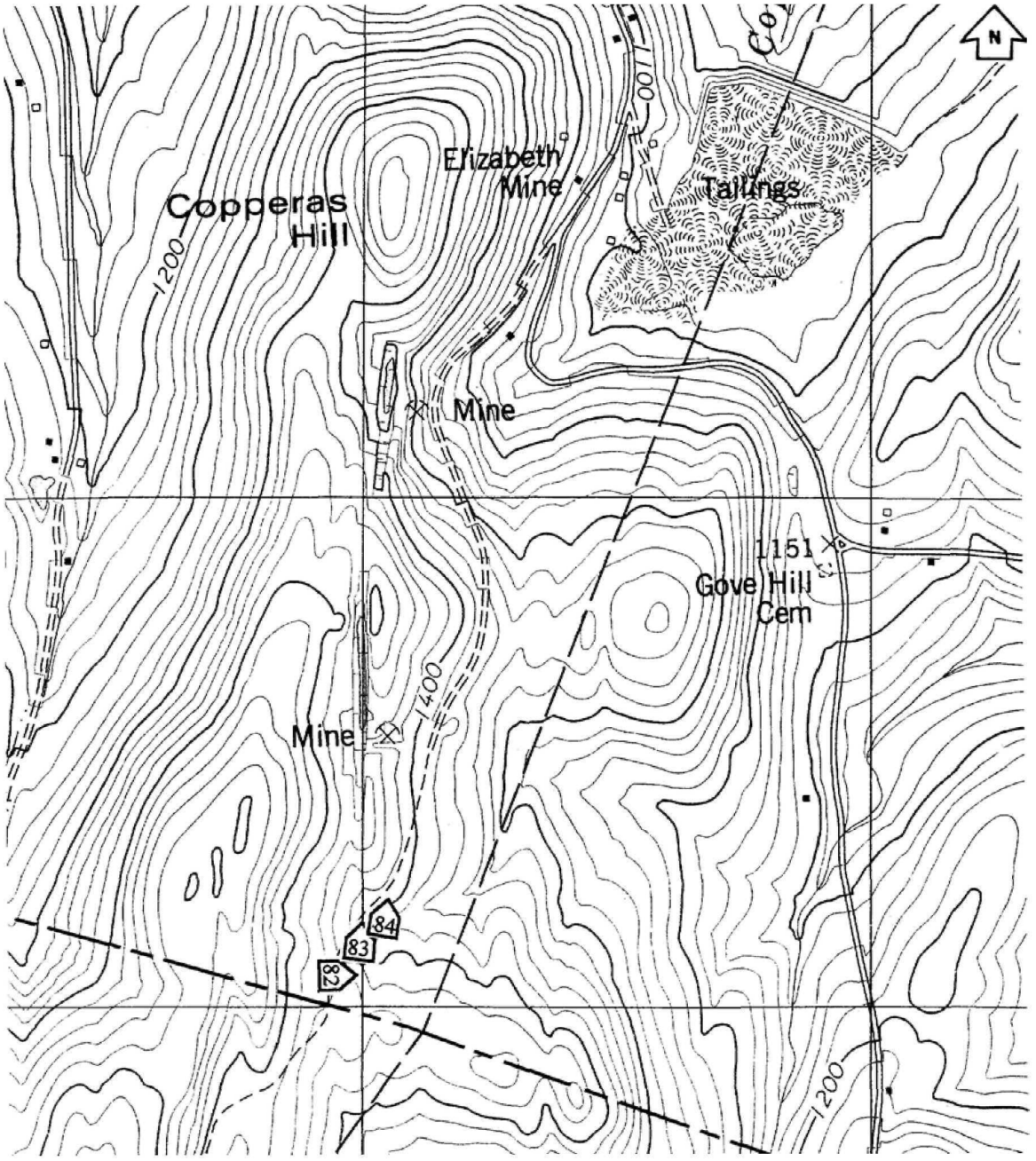
North Open Cut and Copperas Works Area



South Open Cut



Old South Mine



HISTORIC AMERICAN ENGINEERING RECORD

ELIZABETH MINE

HAER No. VT-35

Location: Mine Road, 1.75 miles southeast of the intersection of Vermont Route 132 and Mine Road in the village of South Strafford
Orange County, Vermont
USGS South Strafford Quadrangle, Universal Transverse Mercator Coordinates: 18.714570. 4855625

Dates of Construction: 1942-1958

Engineer, etc.: Galigher Company, Salt Lake City, Utah ca. 1943 buildings)

Present Owner (s): privately owned (withheld by request)

Present Use: closed (1958)

Significance: The Elizabeth Mine is one of three copper mines that operated in Orange County, VT, in the nineteenth and twentieth centuries. The Elizabeth Mine operated almost continuously from 1809 to 1958. Of the three mines, it produced the highest tonnage of copper, and left the largest and most complex mining landscape. Beginning in 1809 the mine became an important domestic producer of copperas (iron sulfate), and copper was smelted in several brief campaigns between 1830 and 1919. The mine experienced its greatest productivity between 1943 and 1958 when it was revived using modern ore processing technology. Between 1946 and 1956 the Elizabeth Mine was among the top 25 copper producers in the U.S. Total copper output for the mine is estimated at more than 100 million lbs. The site today encompasses historic mining resources including a regionally unique cluster of World War II-era hard rock metal mining and ore processing buildings and associated landscape features including tailings and waste rock piles, all reflective of historically significant activities and processes at the site.

Historian: Matthew A. Kierstead, November 2003

Project Information: The Elizabeth Mine has been determined to be a source of water contamination in the West Branch of the Ompompanoosuc River, a tributary of the Connecticut River. The U.S. Environmental Protection Agency listed the Elizabeth Mine site on the National Priority List ("Superfund") on June 14, 2001. The site was subsequently determined eligible for listing in the National Register of Historic Places. This Historic American Engineering Record documentation of the World War II to 1958-era historic architectural, engineering and landscape resources at the Elizabeth Mine site was completed during spring and summer 2003 by PAL for the U.S. Army Corps

of Engineers in partial fulfillment of a Memorandum of Agreement stipulating mitigation of potential cleanup impacts to historic resources.

CHRONOLOGY

1793 Ore deposit discovered on Copperas Hill

1809 Vermont Mineral Factory Company conducting surface mining and copperas production

1817 U.S. President James Monroe visits mine on goodwill tour

1830 Underground mining begins; Isaac Tyson, Jr. smelts first copper at Furnace Flats

1854 Copper smelting at Furnace Flats through 1867

1882 Copperas production ceases; James Tyson names mine "Elizabeth" after his wife; Tysons smelt copper at Sargent Brook to 1890

1898 Tysons dig 1898 Adit; smelt copper on east side of Copperas Hill through 1902

1906 Mine purchased by August Heckscher; new smelters installed

1916 First flotation milling at Elizabeth Mine

1925 American Metals Company operates mine

1928 National Copper Corporation and Frederick Foote operate mine

1942 Vermont Copper Company organized, begins construction and reopens mine

1943 First copper concentrate from Elizabeth Mine mill

1948 New adit and shaft dug to develop 975 ft level

1949 New crusher and equipment added for extra capacity, ore extraction begins from waste dumps, South Open Cut, and Ely Mine dumps

1950 Production reaches 7 million lbs

1952 Pyrrhotite extraction for Brown Paper Company begins; Tailings Pile 2 started

1954 Production exceeds 8.5 million lbs; Appalachian Sulphides, Inc. purchases Elizabeth Mine from Vermont Copper Company, Inc.

1958 Ore exhausted as mining progresses on 975 ft level north of Ompompanoosuc River; Appalachian Sulphides, Inc. closes Elizabeth Mine

INTRODUCTION

The Elizabeth Mine is one of three copper mines that operated in the Orange County, VT, "Copper Belt" in the nineteenth and twentieth centuries. The Elizabeth Mine operated almost continuously from 1809 to 1958. Of the three Vermont Copper Belt mines, it produced the highest tonnage of copper, and left the largest and most complex mining landscape. Mining began in 1809 for the production of copperas (iron sulfate), and copper was smelted in several brief campaigns between 1830 and 1919. The Elizabeth Mine experienced its greatest productivity between 1942 and 1958 when it was revived using modern ore processing technology. Between 1946 and 1956 the Elizabeth Mine was among the top 25 copper producers in the U.S. Total copper output for the mine is estimated at more than 100,000,000 lbs of copper (Kierstead 2000:E2-4, 3/10-11, 7/1-3). The Elizabeth Mine site today includes historic mining resources including a regionally unique cluster of World War II-era hard rock metal mining and ore processing buildings and associated landscape features including tailings and waste rock piles, all reflective of historically significant activities and processes at the site.

The tailings piles and waste rock at the Elizabeth Mine have been determined to be a source of water contamination in the West Branch of the Ompompanoosuc River, a tributary of the Connecticut River. The Elizabeth Mine site was listed in the U.S. Environmental Protection Agency's National Priorities List (NPL or "Superfund") on June 14, 2001. The site was subsequently determined eligible for listing in the National Register of Historic Places (Kierstead 2000:7/1-3). This Historic American Engineering Record (HAER) documentation of the World War II to 1958-era historic architectural, engineering and landscape resources at the Elizabeth Mine site was completed by PAL for the U.S. Army Corps of Engineers in partial fulfillment of mitigation of

potential contamination cleanup impacts to the historic resources at the site.

This HAER documentation concentrates on the history, buildings, processes, and landscape associated with 1942 to 1958 operations at the Elizabeth Mine. The approximately 2 square mile area comprising the Elizabeth Mine Site contains hundreds of historic industrial and domestic structural, archaeological, and landscape resources dating from the nineteenth and twentieth centuries that represent many phases of activity at the Elizabeth Mine. The most coherent and visible part of the Elizabeth Mine Site is the core mine area centered on Mine Road, which contains resources associated with and resulting from the activities that took place between 1942 and 1958. This area includes multiple standing structures and massive waste piles and clearly illustrates mining and materials handling processes and technology. This component of the Elizabeth Mine site is therefore an appropriate candidate for HAER documentation methodology. This documentation also includes peripheral and distal structural and landscape resources associated with the mid-twentieth-century period of activity. The Elizabeth Mine Site does contain earlier large-scale archaeological features that have been documented elsewhere through historical research and archaeological survey, including the Copperas Works Site, Furnace Flats North and South, Sargent Brook smelter site, and numerous domestic resource clusters (Ford et al. 2003); and earlier and associated landscapes that have been documented in aerial and terrestrial 35mm color transparencies (Copperas Works Site, Tailings Pile 1 [TP 1] and Tailings Pile 2 [TP 2], Old South Mine, South Open Cut, North Open Cut, Tyson Mining Area, and the WW II-era buildings)(Kierstead 2003).

LOCATION

The majority of the Elizabeth Mine Site is located in Orange County, Vermont, approximately 12 miles north of White River Junction and approximately 10 miles west of the Connecticut River (Figure 1). The roughly 800-acre site is located southeast of the village of South Strafford in the southeastern corner of the town of Strafford, with an eastern portion in Thetford and small portions at its southern extremity in Sharon and Norwich, which are located in Windsor County. The site is located within the drainages of Copperas Brook and Lord Brook, which flow north and east to the West Branch of the Ompompanoosuc River, a major tributary of the Connecticut River located approximately 1 mile north of the site. The Elizabeth Mine Site is roughly diamond shaped, stretching from the Air Shaft and Electrical Substation on the north bank of the Ompompanoosuc River in the Rte 132-Furnace Road vicinity in Strafford, to a point approximately 2 miles south at the waste rock and prospect pits south of the Old South Mine in the extreme northeast corner of the town of Sharon; and from the Sargent Brook smelter site at the west foot of Copperas Hill in Strafford to a point approximately 1 mile east at the east tip of Tailings Pile 1 at the west foot of Gove Hill in Thetford (Figure 2). The core of the mine site that includes the mid-twentieth-century resources in this documentation is located in the east-central part of the diamond-shaped area, in the Copperas Brook valley on the east flank of Copperas Hill, west of Gove Hill, approximately 1.75 miles southeast of the intersection of Vermont Route 132 and Mine Road in the village of South Strafford (Figure 3).

GEOLOGY

The Elizabeth Mine is the southernmost mine in the 20-mile long, Orange County, VT, Copper Belt that includes the Ely Mine at Vershire and the Pike Hill mines at Corinth (Figure 4). These metallic sulfide mineral deposits are located in the Paleozoic stratigraphic units of the Connecticut Valley Trough that stretches from western Massachusetts to the Gaspe Peninsula in Canada. The bedrock underlying Orange County consists of Silurian and early Devonian metasediments with interspersed metavolcanics and igneous intrusives (Doll et al. 1961). These rocks were subjected to at least three stages of intense folding and metamorphism during the early Devonian Acadian (400 my) orogeny. Rock units typically dip steeply to the east, and become progressively younger from west to east. The Elizabeth Mine orebody is hosted by the Gile Mountain formation, which consists largely of metamorphosed pelite and graywacke (seafloor sediments) (Figure 5) (Seal et al. 2001:116; Slack et al. 2001:194).

The Vermont Copper Belt ore deposits are examples of one of the major classes of metallic ore deposits found in the eastern United States, the group known as the Appalachian Sulfides. These ore deposits consist of iron sulfide in the form of pyrite or pyrrhotite, often mixed with lesser quantities of copper, usually in the form of chalcopyrite, and sometimes zinc (sphalerite), lead and trace amounts of other, sometimes precious, metals. These orebodies were deposited on ancient seafloor as thick sulfide ore beds by hydrothermal vents precipitating metals leached from undersea magma by hot circulating seawater. These sulfide beds were eventually buried by sediments, incorporated into new continental crust, emplaced and metamorphosed in folded

mountain ranges, and eroded, exposing them for discovery. Appalachian sulfide deposits stretch from Alabama to Maine, and continue into New Brunswick, Canada (Kierstead 2000:3.6-3.7). These ore deposits have been further classified into subgroups according to their original depositional environment. The Orange County copper deposits are "Besshi" type deposits, named for their type locality in the Sea of Japan. These deposits occur at rifting (spreading) continental plate margins at oceanic ridge crests or back arc marine basins. The depositional environment of the Orange County deposits is considered analogous to that of the Gorda Ridge and Juan de Fuca Ridge in the eastern Pacific Ocean today (Seal et al. 2001:116; Slack et al. 2001:194, 196, 208-209).

Appalachian sulfide orebodies are typically stratiform and stratabound, that is they conform to and are bound by their host rock layers. Many have been subjected to intense deformation and remobilization. The orebodies are typically pod-like, lenticular, or tabular in shape, steeply dipping, and often swell and pinch or form overlapping, *en echelon* lenses. They are generally massive and fairly sharply bound by their schistose host rock. The Elizabeth Mine orebody is thought to be emplaced in the limb and crest of an anticlinal fold. It is a north-south trending, elongate, tabular, sheet-like deposit of nearly continuous massive sulfide measuring approximately 11,000 ft long along its strike. It varies in width from a few feet to several dozen feet. It dips approximately 70 degrees to the east and plunges from ground surface at the North Open Cut to a depth of approximately 1,000 ft at its northern terminus north of the West Branch of the Ompompanoosuc River. The ore is more or less continuous, massive to somewhat disseminated sulfide, with some local splits, rolls, and irregularities in width. At its southern end, this steeply dipping sheet was also longitudinally folded into a series

of undulations. This section of the orebody and its host rock was subsequently eroded to the current surface elevation. The ore outcrops at the South Open Cut and Old South Mine are the remnant bottoms of these undulating folds.

The topography at the Elizabeth Mine and the shape and orientation of the orebody within its host rock played an important role in the development of the industrial landscape. The North Open Cut orebody outcrops at the east shoulder of Copperas Hill, at an elevation of 1,300 to 1,400 ft above sea level. The bowl-shaped hillside below the cut drops to an elevation of 1,140 ft at Mine Road. This natural hillside amphitheater, which includes springs and is the headwaters of Copperas Brook, provided a fortuitous landscape for the nineteenth-century gravity and water-fed, cascading copperas manufacturing process. As the north-south oriented orebody was exploited increasingly to the north and deeper underground as time progressed, infrastructure and activity followed the trend of the ore. First mined from an open cut, the plunging shape of the orebody required new access points from progressively longer adits (horizontal tunnels) to the east down the slope of Copperas Hill during the mid-nineteenth century. In the 1880s the northward trend of the ore dictated that shafts be located north of the North Open Cut, and that an adit be located even further north in 1898. This trend continued into the mid-twentieth-century period covered by this documentation. By 1948, the northward and downward progress of mining required the driving of yet another adit and intersecting shaft further north, east of the ore trend. These shifting mine access points and their immediate topography also dictated the location of processing facilities and waste deposits. The sloping topography of the Copperas Brook valley allowed placement of the cascading processes of the World War II-era ore crushing and

flotation plants, and aided the nearby, down slope deposition of mill tailings pumped in a water slurry.

HISTORY

Vermont Copper Belt

The Elizabeth Mine is one of three major copper mines that operated in the 20-mile long Orange County, VT, Copper Belt during the nineteenth and twentieth centuries. Copper production in the eastern U.S. during this period was minuscule compared to the output of the U.S. and even some individual U.S. mines. Although the large operations of the American West have dominated U.S. copper production since the early twentieth century, several eastern U.S. copper mines were reopened and worked profitably at times when wartime demand warranted it or prices were high enough, and they could be operated efficiently with proven technology. Several Appalachian sulfide mines, including the Elizabeth Mine, did not experience their greatest phase of productivity until the application of modern mass production technology in the mid-twentieth century (Kierstead et al. 2003:87).

The Elizabeth Mine operated almost continuously from 1809 to 1958. Of the three Vermont Copper Belt mines, it produced the highest tonnage of copper, and left the largest and most complex mining landscape. Mining began in 1809 for the production of copperas, or iron sulfate, an important industrial chemical. This operation eventually became a major domestic source of copperas until it closed in the early 1880s. President James Monroe visited the Elizabeth Mine in 1817 as part of a goodwill tour including area industries. Copper was smelted beginning about 1830 and in eight brief

subsequent campaigns until 1919. The mine was revived for World War II and closed in 1958. The mine was the scene of several important firsts in American copper metallurgy, including successful mine side smelting, large-scale smelting of sulfide ores, smelting with hot blast and anthracite, and successful use of chromite refractories. Elizabeth Mine probably had a total lifetime output of more than 100,000,000 lbs of copper (Kierstead et al. 2003:88).

The Ely Mine in Vershire was an active copper producer between the mid-1850s and 1918, with its greatest production realized during the 1870s and 1880s. During this period, Ely Mine outstripped copper production at the Elizabeth Mine and ranked among the top ten copper producing mines in the U.S. The Ely Mine often contributed more than 2 million lbs of pig copper, and sometimes more than 3 million, to annual U.S. output during the 1870s and was still productive into the 1890s. It was the third largest-producing U.S. copper mine in 1873 and 1875, and ranked from fourth to ninth in the rest of that decade. The Ely Mine included a large copper smelter building, erected in 1867 and ultimately reaching more than 1,000 ft in length. The mine fostered the growth of a substantial workers' village that influenced the local economy. The mine was the scene of labor unrest that resulted in the "Ely War." Under operators including Frederic Cazin and George Westinghouse, the mine was the site of several late-nineteenth and early-twentieth-century efforts aimed at efficient extraction of copper from low grade ores and mine wastes and new smelting furnace technology. Ely Mine was the only copper mine in Vermont where all technological aspects of refined pig copper production, from mining of raw ore to smelting of refined copper, were successfully integrated on a large scale. The mine's overall lifetime

production of copper stands somewhere between 30 and 40 million lbs (Kierstead et al. 2003:87-88).

The Pike Hill Mines in Corinth were the scene of intermittent copper mining from 1846 to 1919. Although the Pike Hill mines operated sporadically and were overshadowed by the Ely Mine and the Elizabeth Mine, they contributed an estimated 1/17th of the copper produced in the Orange County Copper Belt. There was no smelting at Pike Hill; ore mined there was taken to Ely to be refined. The total copper production of the Pike Hill mines is estimated at 8,600,000 lbs (Kierstead et al. 2003:88-89).

Lack of complete and consistent nineteenth-century records makes accurate estimation of Vermont's total copper output difficult. However, based on conservative analysis of existing records it appears certain that Vermont was the second-largest copper-producing state for at least part of the 1870s. The major producers in order of production during the 1860s and 1870s were Michigan, Vermont and Tennessee. Vermont was far behind Michigan, which produced more than 60 percent of domestic copper from 1854 to 1882. The 1880 census placed Vermont, with 2,647,894 lbs. of copper, in third place behind Michigan's 40,389,212 lbs., and Arizona's 3,183,750 lbs. By 1882 the western mines began to pull ahead, and Vermont ceased to be a major contributor to U.S. copper production. Industrial production figures for the mid-twentieth century are more accurate. In 1953 the Elizabeth Mine was the nineteenth highest producing copper mine in the U.S. Between 1946 through 1956 it was among the top 25 producers and was twentieth in five of those years. In 1950 there were 300 copper mines in the country. The top five produced 67 percent of U.S. copper and the top ten produced 85 percent. Total copper output for the Orange County Copper mines between 1793 and 1958 has been estimated at

about 145 million lbs., with about 100 million from the Elizabeth Mine, about 35 million lbs. from Ely, and less than 10 million from Pike Hill (Abbott 1964: 144, 336-338, 444-448; Howard 1969:10).

Elizabeth Mine

Pre-mining history

Strafford, VT, was chartered August 12, 1761. Strafford remained a frontier town through the Revolutionary War and settlement did not begin to increase until Vermont was admitted into the Union in 1791. The main economic activity in Strafford during the late eighteenth century was subsistence farming with limited local trade. Industry consisted of a few sawmills, gristmills, tanneries, and fulling mills supplying local needs. The South Strafford orebody was discovered in 1798. Its primary constituent is pyrrhotite, an iron-sulfur mineral that lay below a weathered iron oxide cap. Deeds associated with the land from the late 1790s refer to iron ore mining rights. The belief that the weathered surface material could be smelted for iron persisted until 1809, when a misguided attempt to smelt this unsuitable ore choked the Franconia, NH, iron furnace (Kierstead 2000:4/1-2).

Copperas Manufacturing

The first product manufactured from the South Strafford ore was copperas, a crystalline green hydrous iron sulfate that was an important early industrial chemical compound. It was used as a disinfectant, astringent, and wood preservative. It added color permanence to black and brown dyes and was widely used in the dyeing and tanning industry. The 1807 Embargo Act

restricted chemical imports, which spurred domestic copperas production. The Vermont Mineral Factory Company began copperas production at South Strafford in 1809. After the war English copperas flooded the market and made the works unprofitable. In 1817 President James Monroe visited the works as part of a goodwill tour, and the company was successful in inducing him to enact a beneficial import tariff on copperas imports. Production reached 1,000 tons in 1831, when the works reportedly made 75 percent of domestically produced copperas (Kierstead 2000:4/2 5).

Copperas production was a simple process that was well documented at the Elizabeth Mine. The raw material was pyrrhotite gathered by excavation. The process made use of gravity and the flow of water. The ore was piled into beds, where it was roasted to promote breakage of the ore and release of the sulfur. The beds were on elevated and cleared surfaces. Once roasted, the ore was moved to leaching heaps where water was percolated through it to release a liquor of ferrous sulfate and sulfuric acid, which was run through plank-lined channels to a large holding cistern. The liquid was pumped into lead-lined boilers and when sufficiently concentrated, it was poured into pans where it crystallized and was scraped off and packaged for shipment (Kierstead 2000:4/5-12; Smith 2000).

Until about 1830 the South Strafford copperas works drew its raw material from the North Open Cut, located near the top of Copperas Hill. About 1829 the company began developing underground workings to access the ore more efficiently. Establishment of local railroad service in 1848 improved transportation and copperas was shipped to cities including Baltimore, MD; Boston, MA; Charlestown, SC; Hartford, CT; Richmond, VA; and Troy, NY. The copperas from South Strafford was used primarily by the woolen, cotton,

dyeing, and hatmaking industries. In 1882 the works were shut down because cheaper iron sulfate was available from byproducts of the burgeoning tinplate industry. At its peak, the scale of the Copperas Works in terms of its landscape and factory buildings far exceeded that of any other manufacturing concerns in the area (Abbott 1964:7-19, 271-279).

Copper

Nineteenth-Century Operations

Although copperas production dominated nineteenth-century activity at South Strafford, the ore also contained the copper-bearing sulfide ore chalcopyrite, and efforts to smelt copper also took place. By the early 1830s the Vermont Mineral Factory Company began underground mining and acquired the land on the Ompompanoosuc River at Furnace Flats, approximately 1 mile north of the mine. There, with the aid of Baltimore, MD, metallurgist Isaac Tyson, Jr. (1792-1861) copper was smelted in several vertical shaft blast furnaces. This smelting produced impure copper "matte" shipped elsewhere for final refining. This remote smelting plant was an unusually large and unprecedented operation, and was the site of the first use of anthracite and hot blast for copper smelting, the first successful large-scale smelting of sulfide ores in a masonry-lined furnace, and what may have been the first successful mine-side smelting of copper in the U.S. This operation shut down with the Panic of 1837. The Vermont Copperas Company resumed smelting at Furnace Flats between 1854 and 1867, when prices fell after the Civil War. About 1884 the Strafford Mining Company smelted copper at this location on a small scale (Abbott 1964: 271-273; Johnsson 2001:42-44).

In the early 1880s the Tyson family returned to South Strafford to mine and smelt copper. Isaac Tyson, Jr.'s son, James W. Tyson, named the operation the Elizabeth Mining Company after his wife, Elizabeth, and brought his son, James, Jr., to work the mines. For more than 20 years the Tysons developed the mine and smelted copper in several furnaces. Tyson sank a new shaft just north of the North Open Cut, and made matte and pig copper at a new smelter on Sargent Brook, west of Copperas Hill, between 1882 and 1890. In 1895 the Tysons began to drive a new 1,400 ft adit (horizontal tunnel) located lower down on the fast slope of Copperas Hill, northeast of the copperas works site, to access the north trending orebody. They built a mechanical ore concentration mill and smelting plant northeast of the adit. At the new smelter metallurgist William Glenn performed the first successful smelting with chromite furnace linings, a major contribution to smelting that greatly prolonged the life of furnace linings. The remote operation was not profitable and shut down in 1902 (Johnsson 2001:44-60).

Early-Twentieth-Century Operations

Demand for copper rose sharply at the end of the nineteenth century because of the increasing need for the metal in electrical communication and power equipment. High-grade copper deposits were dwindling and the need for more copper drove metallurgists to develop processes to efficiently extract copper from leaner and leaner ores. New processing technology, electrically powered equipment, and the application of mass-production techniques allowed savings in fuel and labor and the realization of greater and greater economies of scale in mining. Ultimately these advances made possible the profitable mining and milling of immense low-grade deposits in open pits. At the Elizabeth Mine, the new technologies of pyritic smelting and flotation were

both applied in dogged efforts to make this large copper deposit a paying proposition.

In 1906 the Elizabeth Mine was purchased by August Heckscher (1848-1941), known for his creation of the New Jersey Zinc Company. Heckscher formed the Vermont Copper Corporation and built a blast furnace configured for pyritic smelting, a then newly emerging method designed to save fuel by burning the sulfur in the ore. This technologically up to date works, which was the first at the site powered by electricity, was damaged in a series of fires. In 1916 the Vermont Copper Corporation reopened the mine and again attempted pyritic smelting with an improved furnace located higher up on the east flank of Copperas Hill. This operation was briefly profitable because of high World War I copper prices but closed in 1919 (Kierstead 2000:4/25-27).

The 1916 operation was the first at the Elizabeth Mine to use froth flotation technology. The development of froth flotation, first used commercially in Australia in 1905, is considered the birth of the modern mining industry. The process relies on the attraction of fine particles of metallic ore to chemically treated bubbles. The process involves tumbling metallic ore in a series of ball and/or rod mills, large electrically driven rotating drums filled with steel balls or rods to grind the ore to a fine consistency. The fine ore is then added to rectangular tubs filled with water and special flotation reagents, and agitated with rising bubbles and motorized paddles. The metallic ore particles are attracted to the floating bubbles that rise to the top and are skimmed off, and the fine waste rock mill tailings are removed from the bottom of the flotation tubs. The result is a copper concentrate powder rich enough to be economically shipped to an off-site smelter. The first commercial froth flotation mill in the United States was

installed at the Black Rock Mine at Butte, MT, in 1912. In 1914 there were 42 flotation mills operating in the U.S. (Bunyak 1998:29-30; Kierstead 2000:4/31; Wark 1938:15-28).

Flotation was applied at all three Orange County copper mines during the World War I period. At the Ely Mine, Ely-Copperfield Associates built a 250-ton per day flotation plant that produced 3,600 lbs of copper during its 10-month 1918 campaign. Flotation was also employed at the Pike Hill Mine, with the experimental Wood process tested in 1906, and a more conventional process applied in 1916-1919 (Abbott 1964:306-307, 188; Jacobs 1918:143-145; Kierstead et al. 2003:258-275).

At the Elizabeth Mine, two more attempts to make copper concentrate were made before the onset of the Great Depression. In 1925 the American Metals Company, a worldwide investor in copper properties, mined 20,000 tons of ore and milled 1,756 tons of 18 percent copper concentrate, using the flotation mill to process the ore. Frederick W. Foote, a mining engineer with experience in sulfide ores who was convinced that the Elizabeth Mine could be profitable if the copper, iron, and sulfur could be extracted, championed the final effort. In 1928 Foote convinced backers to form the National Copper Corporation, which mined and milled 60,000 tons of ore in the re-equipped old Tyson mill between April 1929 and June 1930, producing 6,330 tons of concentrates before the plant was closed because of falling copper prices. Under Foote, the flotation mill reached its predicted output of 300 to 350 tons per day of 20 percent copper concentrate and recovered more than 90 percent of the copper in the ore. Experiments proved that the iron-sulfur content present in the pyrrhotite could be extracted through flotation. In 1931 Foote thoroughly analyzed the mine and proposed construction of a 500

ton-per-day mill. Exploratory drilling revealed proven ore reserves of 1,565,00 tons of ore carrying 1.76 percent copper in an area 13,000 ft long and 1,500 ft deep, enough for 10 years of operation, but the ore was low grade, hard to mine and beneficiate, and remote from sources of power and transportation. When National Copper's lease expired, Foote took an option on the property for $50,000, and waited for market conditions to change (Abbott 1964:283-287; Randolph Herald 1940).

WWII and Korean War Era, 1941 to 1958: Vermont Copper Company, Inc. and Appalachian Sulfides, Inc.

As early as 1940 the U.S. government began to look to the Vermont Copper Belt as a potential source of strategic metals for the World War II effort, and after Pearl Harbor, interest in the Elizabeth Mine as a source of copper grew. George Adams Ellis, a Vermont-born financier and industrialist, worked with the Vermont War Production Board to reopen the mine. Former Vermont Governor Stanley C. Wilson was also involved. The Vermont Copper Company, Inc., was organized in April 1942 with Ellis as president. The company acquired the Strafford, Vershire, and Corinth mining properties and spent $2,350,000 worth of private investments and loans to develop the Elizabeth Mine. Frederick Foote was retained as a consultant. U.S. Bureau of Mines drilling tests showed that 16.5 million lbs. of copper could be produced within two years. The company soon signed an agreement with the Metals Reserve Corporation of the Reconstruction Finance Corporation for 16.5 million lbs of copper. The company also received a $550,000 loan from the MRC (Abbott 1964:308-313; Randolph Herald 1942).

Redevelopment work included clearing and pumping out the underground workings. By May 1942, 200 men were employed cleaning and rebuilding the mine. The 1898 Tyson Adit was straightened and enlarged (Figure 6). A 12.5-mile paved highway (that closely followed present-day Vermont Route 132) was built to the Boston & Maine Railroad at Pompanoosuc, a 7.5 mile electrical line was built to the mine, and a water line was run to a new pump house on the south bank of the Ompompanoosuc River, east of the area where Isaac Tyson smelted copper in the 1830s. The late 1890s Tyson era mill and smelter buildings clustered around the 1898 (or 300 ft level) Adit were torn down, the land was regraded, and a new complex of mine buildings was built (Figures 7, 8, and 9). These buildings included a Change House, Compressor Building, Machine Shop/Workshop, and Office/Warehouse in a straight line on a flat terrace east and north of the 1898 adit (Figure 10). A Crushing Plant, Concentrating Mill, and Thickener/Filter building were located in tiers on the hillside below to take advantage of the flow of water and gravity in the beneficiation process (Figure 11). The Galigher Company of Salt Lake City, UT, designed and built the 500-ton per day Concentrating Mill, and made arrangements for tailings disposal and water supply. Other ancillary buildings included a Heating Plant, Garage, Assay Laboratory, two water tank buildings, an Infirmary, and a Boardinghouse. New rails and overhead electric wires were strung for the mine cars connecting the 1898 Adit with the Crushing Plant (Figures 12 and 13). In August 1942 the U.S. Government gave the mine a contract for 16.5 million lbs. of copper. Ore production began in the spring of 1943, but the mill was not ready to process ore until October. By November the system was operating 24 hours a day, but did not reach its full capacity for several years because of technical difficulties. The copper concentrate was shipped to a Phelps-Dodge Copper Company smelter

at Laurel Hill, Long Island, for refining (Abbott 1964:312-316; Randolph Herald 1942, 1943a).

The copper concentrate was shipped in at least two truckloads per day to the Boston & Maine Railroad at Pompanoosuc Station. The concentrate was transferred from the trucks into railroad cars for shipment to the smelter. After the paving of the highway to Pompanoosuc during early World War II Operations it continued to be the shipment point for incoming equipment and supplies and outgoing ore. The mine company constructed the "copper shed" across the road from the station. It is a long, narrow, tall, gable-roofed building located parallel to the tracks, with the same tan asphalt siding used on the World War II-era buildings at the mine site. This building was used to store rail cars loaded with ore concentrate.

Because of a shortage of labor during the war, and skilled labor in general, the mine did not reach full capacity until the 1950s. Fifty miners from Newfoundland were imported to ease the labor shortage. The quality of the ore and the efficiency of the milling process fluctuated during this period. The mine produced an average of 300,000 lbs. of copper concentrate a month through 1944, for a year-end total of 3,810,881 lbs. After the end of World War II, labor shortages persisted and the price of copper fell. Production in 1945 fell to 3,777,718 lbs, rose to 6,064,572 lbs in 1946, and fell back to 4,495,054 lbs in 1947. By that year copper shortages cropped up again and the price rose, but the mine was only marginally profitable. The mine had been losing $15,000 to $20,000 a month for two years. As mining progressed deeper and further north, tramming and hoisting the ore up and south almost 2,000 ft to the 1898 Tyson Adit at the 300 ft level became an inefficient way to move it out of the mine. In 1948 a new vertical shaft and adit were

excavated north of the 1898 Adit that allowed access to new areas of ore containing 10,000,000 lbs of copper on a new 975 ft level. The Vermont Copper Company realized that in order for the mine to be profitable it would also have to produce other values from the ore. A total of $250,000 was expended on experiments to extract pure iron from the mill tailings through an electrolytic process, which proved fruitless. The copper content of the newly developed ore was lower than anticipated and output for 1948 was only 4,415,865 lbs. The mine required more exploration and increased plant capacity to produce at a scale that would insure profitability, and the Vermont Copper Company sought government assistance. In early 1949 the company was awarded a contract with the U.S. government for 30 million lbs of copper at 19.25 cents per lb. for four years, and received a $150,000 government loan (Abbott 1964:320-326).

The new contract, loan, and ore reserves suggested a profitable future but management changes were also in order. The mine took on Frank Eichelberger as president and general manager. Eichelberger was a mining engineer with a reputation for running profitable operations and who had been a pioneer in the development of froth flotation. He instituted cost-cutting measures and concentrated on mining the best underground ore at his disposal and increasing the overall volume of ore running through the mill to maximize the economy of scale. A recession in early 1949 lowered the price of copper to 16 cents per lb and the Phelps Dodge refinery went on strike. However, by June 1949 the mine turned its first profit, and the Reconstruction Finance Corporation funded construction of a larger primary crusher plant. The capacities of the mill's various departments were tuned and matched for increased output of 750 tons per day to meet the increased ore production

capacity. Copper output rose to 600,000 lbs per month and 1949 production figures totaled 6,094,980 lbs (Abbott 1964:327-332).

Between July 1949 and March 1950 the company mixed 55,000 tons of dump ore from the Tyson mining area north of the North Open Cut (Figure 14), plus dump ore from the Ely Mine, with fresh underground ore from the Elizabeth Mine. The 60,000 tons of Ely dump ore mined in 1950 yielded 1,200,000 lbs of copper, however, the oxidized dump ore interfered with the flotation process and after March 1, 1950, all the ore milled at the Elizabeth Mine was fresh underground material (Benson et al. 1950:23).

By April 1950 the price of copper rose again and was more than 24 cents per lb by the end of the year. New exploration proved reserves of economically suitable ore all the way north to the Ompompanoosuc River. The South Open Cut was started by that time (Figure 15). This 1,600 ft long, narrow, steeply dipping exposure of the orebody was located several hundred feet south of the North Open Cut. The contract for excavation of the ore was given to a private contractor, who blasted the ore free, excavated it with a cable-shovel, and trucked it to the mill on a new road built down the east flank of Copperas Hill, across the former copperas works area. This activity did not extend underground and resulted in a long, narrow, steep-walled trench, now partially filled with water. Excavation of the South Open Cut included blasting a small connecting tunnel to the North Open Cut, and a small, perpendicular crosscut from the road west to the orebody to facilitate truck access. The waste rock from this development was dumped in a pile east of the cut and the haul road. The South Open Cut operation was short-lived, but it did provide a boost in the quantity of fresh ore for the mill. In 1950

the mine reached a new record production high of 7,000,000 lbs (Abbott 1964:332-335).

In 1951 domestic sulfur shortages finally led to the realization of plans to extract sulfur from the ore under a contract with the Brown Paper Company of Berlin, NH, which wanted the sulfur for sulfite process wood pulp treatment for papermaking. The process would leave behind iron that could also be sold as a by product. This required building an addition to the east end of the flotation mill to include extra flotation cells to remove the pyrrhotite from the tailings after the chalcopyrite was extracted. By 1952 this new equipment was producing 20,000 to 25,000 tons of pyrrhotite concentrates a year. By 1952 TP 1 had grown to fill the valley between Copperas Hill and Gove Hill to the east (Figures 16 and 17). When the new flotation cells went on line, TP 2 was started south of TP 1 to keep the tailings segregated (Abbott 1964:336-338; Condict, personal communication 2003).

The price and demand for copper rose with the Korean War and in 1951 more ore was developed north of the 975 ft level, raising estimates of ore reserves by 670,000 tons. In 1954, after the war, the company signed a government contract for 12,000,000 lbs at just more than 31 cents per lb. In June of that year the mine was purchased by Appalachian Sulphides, Inc., a subsidiary of Ventures-Nippissing of Canada, for $365,000. Under the new owner, mining rights increased to more than 8,000 acres along the Vermont Copper Belt. The company intensively prospected for more ore at the Elizabeth and other former mining sites in Vermont and elsewhere in the Appalachian Mountain chain. The mid-1950s were highly productive for the Elizabeth Mine because of improvements in equipment and a steady labor force. Although annual production never reached 10 million lbs, it rose above 8,500,000 lbs in 1954

and 1955. Monthly production rose from 300,000 lbs per month in 1944 to more than 700,000 lbs. The mill went from producing an average of 200 tons per day in 1943 to an average of 800 tons per day in 1952. Recovery of trace amounts of silver and gold at the refinery added to income. Employment at the mine reached a high of 220 workers who lived in 16 surrounding towns. The annual payroll was more than $1 million and sales were more than $3 million. The most successful year was 1955, when the mine yielded $1,016,705 in profits (Abbott 1964:337 339).

Mining eventually progressed north of the Ompompanoosuc River, where two small openings, the Air Shaft and Air Vent, were made to meet the underground workings. Production dropped below 7,000,000 lbs in 1956 and 1957. High-grade copper ore was becoming scarce, copper was again in oversupply, and prices fell from a 90-year peak in 1956. By 1957 the number of employees dropped to 180 and the payroll dropped to $800,000. Appalachian Sulphides had been using profits from the Elizabeth Mine to reopen another historic sulfide copper mine at Ore Knob, NC. In February 1958 Appalachian Sulphides closed the Elizabeth Mine and shipped some of the equipment to Ore Knob. The 1948 adit and shaft entrances were closed and the company abandoned the mine site and buildings. Several of the transient management staff and some of the miners followed the company south, but most of the miners and operational personnel remained in Vermont (Abbott 1964:339-342).

The Elizabeth Mine produced an estimated 10,500,000 lbs of copper before its World War II revival in 1943. During the subsequent 15-year campaign, the mine yielded 91,495,800 lbs of copper, and probably had a total lifetime output of more than 100,000,000 lbs. It ultimately outstripped its nineteenth-century counterpart, the Ely Mine at Vershire. In 1953 the

Elizabeth Mine was the nineteenth highest producing copper mine in the U.S. Between 1946 and 1956 it was among the top 25 producers and was twentieth in five of those years. When it closed, the Elizabeth Mine extended 11,000 ft horizontally and had about 5 miles of underground workings (Abbott 1964:336-340; Howard 1969:8-10).

In 1961 Appalachian Sulfides sold most of the land east of Mine Road, including TP 1 and TP 2, and the World War II era mine buildings, to a local resident, who sold several parcels to other owners beginning in 1969. Since the Elizabeth Mine closed, the mine site has remained undeveloped. The landscape has been impacted to varying degrees by natural processes and human activity. During the 1970s and most of the 1980s the top of TP 1 was a barren expanse of mill tailings. In the mid-1980s the owner attempted to revegetate TP 1 by dumping organic material on its upper surface. This has resulted in the growth of grass and small trees, altering the original appearance of the tailings pile. The buildings have deteriorated because of exposure to the elements. The Compressor Building and the Lower Water Tank Building collapsed under snow load in the winter of 2000-2001 and the Concentrating Mill roof collapsed in the fall of 2003.

DESCRIPTION

General Site Description

This HAER documentation focuses on the 1942-1958 resources including the clusters of buildings on Mine Road, the surrounding shafts and adits where the orebody was accessed, the open cuts where ore was mined, the waste piles

where rock and mill tailings were deposited, and associated transportation and utility features. The nerve center of period operations was the complex of World War II-era buildings approximately 1.75-miles southeast of the village of South Strafford on Mine Road (Figure 18). The core of this complex consists of two clusters of wood frame buildings and a variety of structures arranged on a series of man-made terraces on the eastward-sloping east toe of Copperas Hill, east of Mine Road (Figures 19 and 20). The north-south surface trend of the linear orebody is located approximately ¼ mile to the west of the mine buildings, with the orebody plunging east toward them. Underground access to the orebody was via the 1898 Adit and 1948 Adit (horizontal tunnels), which began at the south and north ends of the building complex, respectively, and extended underground west to intersect the orebody at the 300 ft level. The 1948 Shaft was located above the buildings on the hillside approximately 375 ft west of the 1948 Adit. It intersected the latter working at the 300 ft level and descended to the 975 ft level. The mine also worked surface exposures of the orebody in a pair of north-south oriented linear open cuts located uphill to the southwest. The North Open Cut, a previously mined rock trench approximately 1,000 ft long, is located approximately 2,000 ft southwest of the core mine buildings, west of the Copperas Works Site, the remains of a nineteenth-century iron sulfate manufactory. A pile of 1880s mine waste rock north of this cut was removed for milling for its copper content in 1949-1950. The South Open Cut, located approximately 500 ft south of the North Open Cut, is an approximately 1,600 ft long rock trench that was excavated in 1950-1953). A network of roads connects these ore sources with the mine buildings. Ore milling left TP 1 and TP 2, large piles of sandy waste, east and down slope of the mine buildings in the Copperas Brook valley. These tailings piles occupy a wedge-shaped, north-south oriented area approximately 2,000 ft long that begins

approximately 300 ft east of the mine buildings. TP 1 is the larger and lower of the two and has a 150 ft high, 1,400 ft long north slope. TP 2 is smaller and located at the south end of TP 1. Additional historic mining buildings, structures, and landscape features surround this core area of buildings, waste piles, and mine workings. The following descriptions will begin with the major buildings and surrounding features in the core area and proceed to the more distal features in outlying areas. (For additional information, see the four drawings and 66 black and white photographs that accompany this written narrative).

Mine Buildings and Structures: Description and Function

The entrance to the core mine buildings area is on the east side of Mine Road, just south of a gravel parking area. Two historic mine access roads fork south from this area and lead to the two building clusters and to the tailings piles beyond them to the east. The upper road is closer to mine road and extends south approximately 850 ft before turning 90 degrees east and extending to the north lip of TP 2. The lower road parallels the upper road for approximately 300 ft, passes under a Mine Car Bridge, and then diverges slightly to the southeast for approximately 475 ft, to the west edge of the tailings piles where the southwest tip of TP 1 meets the north tip of TP 2. At a point south of the Garage this road turns back to the north, passing through the lower cluster of ore processing and associated buildings. Both roads are gated close to Mine Road and are unpaved. The area occupied by the upper road and its buildings was prepared by cutting earth from the hillside to the west and filling and terracing the land to the east to form a series of terraces for the road, buildings and mine railroad line, and for fuel pumps and electrical substations further east and downhill.

The upper road served a row of administrative and mechanical and personnel support in a line on the upper terrace. The lower road served ore storage, crushing, milling, and shipment preparation buildings on a lower terrace to the east. Most of the surviving core mine buildings date to the 1942-1943 period when the mine was being reopened for World War II copper production. Previous mine buildings were demolished and the ground recontoured into a series of terraces for the new ones. The construction details were detailed in a 1944 newspaper account:

> The old decrepit buildings were removed to make room for the new ones. Of some two-dozen structures at the mining plant itself, only one of the old structures was saved [this was a ca. 1900 blacksmith shop, no longer extant]. The new ones all have heavy reinforced concrete foundations; those with machinery have cement floors. Strong seasoned pine timbers, formerly used in the Woodbury granite [Company] sheds in Bethel, firmly trussed and bolted, support the framework in the mechanical structures. The walls are covered inside and out with gyplap sheeting, which is fire resistant and, with its contained air chamber, meets the ordeal of cold weather very well. The outer coating is finished to resemble brick, giving the structures a clean, substantial appearance (Randolph Herald 1944).

Out of approximately 30 buildings and structures built in the World War II building campaign, only 14 remain intact and standing. These buildings were constructed to wartime emergency standards and are of functional design. Most were constructed of 2-x-6-inch studs placed on 18-inch centers with horizontal stops every 2 ft. These stops form sealed air compartments for insulation. The frame corners are stabilized with diagonal bracing. The

inside and outside of exterior walls were sheathed with panels of "Gyplap," a U.S. Gypsum Company gypsum construction board. The exteriors were sheathed in textured, buff colored asphalt panels with a common bond brick pattern. Roofs have overhanging eaves with exposed rafter tails and are typically sheathed with black asphalt shingles. Windows are typically six over six, double-hung, wood sash units. Roof trusses are commonly spaced at 2-ft intervals. Reinforced concrete foundations are typically 8 inches thick and were cast in forms using 6 inch wide planks (Wheeler 2000:8 22). Many of these buildings share these construction materials and details. The following individual descriptions provide building-specific information; the general descriptive information noted above can be considered common to all buildings unless specified otherwise.

Office/Warehouse Building

The Office/Warehouse Building is the northernmost building in the row of buildings on the west side of the upper road. It is located approximately 375 ft south of the gravel parking area on Mine Road. It is a narrow rectangular building with its long axis oriented north-south. The building measures 90 ft long by 30 ft wide overall. It is divided into two attached main sections, a 30 ft by 30 ft section to the north, connected to a 60 ft by 30 ft section to the south. The north section is a 2½-story structure with a regular pitch, end gable, asphalt shingled roof. The south section is a one story structure with a moderate pitch, side gable, asphalt shingled roof. A continuous porch runs along the east (front) elevation of the building, visually linking the two sections. On the north section the second floor of the east elevation contains louvered attic vent and a row of six, second floor windows. The north elevation contains two windows on both stories, and

a projecting 9 ft by 4 ft gable roof basement bulkhead shelter. A 17-inch square brick chimney is located west of the bulkhead and rises approximately 8 ft above the eaves of the building. The west (rear) elevation incorporates a 12 ft square, two-story, blank-walled reinforced concrete vault tower with an asphalt shingle gable roof. This vault tower is cut into the hillside west of the building, where an 18 ft long, 8-inch thick retaining wall is connected to the vault by four horizontal steel pipes. The west elevation of the south section of the building has two windows at its north end. The south elevation contains a louvered attic vent and a 23 ft long, 4 ft wide, shed roofed storage shed with multiple vertical plank doors at the ground level. The east elevation of the entire structure is continuous under the full-length porch and contains, from south to north, paneled double doors, a single paneled door, a pair of double windows, a single window, a single paneled door, and a single window. The full-length east porch is six feet wide and has an asphalt roll shed roof with exposed rafter tails and a Gyplap panel ceiling. Ten, 5-inch square posts support the roof. The plank deck is raised 2½ ft off the ground and has a plank wainscot around its perimeter. The interior is divided into hallways and rooms by pressed wood composite panels. The Office/Warehouse Building is in overall good condition; however, the roof is leaking, contributing to accelerated deterioration.

The Office/Warehouse Building was the main administrative building for the mine. It housed the mine's receptionist, and offices for the secretary, geologists, and mine engineers. Interior rooms included offices, a drafting room, a small dormitory, and a pay office. The stacked vaults protected the company's business records and blueprints. It was also a warehouse for mine equipment.

Machine Shop/Workshop

The Machine Shop/Workshop is located 52 ft south of the Office/Warehouse Building, west of the upper road. It is a narrow, rectangular, single-story building with its long axis oriented north-south. The building measures 100 ft long by 30 ft wide. The moderate pitch, side gable roof has three, long, four-by-one-bay, louvered gable roof ventilation monitors with asphalt roll roofing evenly spaced along the ridge. A round sheet metal blacksmith's forge stack rises from the southeast corner of the east roof plane. The east (front) elevation is shaded by a bracketed awning, possibly an early alteration. The east elevation contains, from south to north, a window, a vertical plank door, three windows, and a large mine car door. This 12 ft wide, vertical novelty board door is located 31 ft north of the south end of the building, and has an inset personnel door. The full-length awning is broken by a gable roof projection over this door. The north elevation contains, from east to west, a projecting 9 ft by 4 ft gable roof basement bulkhead shelter set back 8 ft from the east elevation, a square brick chimney with a concrete cap that projects above the roofline, and a 30-panel wood garage overhead roll door that may be a later addition. The west (rear) elevation contains five windows. The south elevation contains a central paneled wood door flanked on each side by a single window. The interior is one large open space with a concrete slab floor. The Machine Shop/Workshop is in overall good condition.

The Machine Shop/Workshop was the central equipment maintenance and repair shop for the mine. A spur track for the mine car rail line led into the east side of the building through the large doors, providing direct transport of equipment to and from the underground workings. The exact equipment housed

in the building is unknown, but a machine shop in a relatively remote facility such as the Elizabeth Mine would have allowed the mine to be self-sufficient for most of its fabrication and machining needs. The shop undoubtedly contained a blacksmith's forge as well as electrically driven metalworking machine tools including a saw, lathe, drill press, planer, etc. Heavy machining and foundry casting work would have been sent offsite.

Oil Storage Shed

The Storage Shed is located 4 ft south of the Machine Shop/Workshop. It is a small, rectangular, 8 ft by 6½ ft, front-gabled, single-story structure that is missing most of its regular pitch roof. The entrance is in the east elevation and consists of a vertical plank door with a sheet metal "Danger - No Smoking" sign. The building is in fair condition and still contains several oil and lubricant drums.

The Oil Storage Shed, although not fireproof and close to other buildings, was used for storing flammable petroleum distillates and lubricants for machine shop and other applications.

Compressor Building

The ruins of the Compressor Building are located approximately 52 ft south of the Machine Shop/Workshop, west of the upper road. The building has collapsed, with the walls now splayed outward and the roof lying within the footprint of the foundation. It was a narrow rectangular single story building measuring approximately 64-x-40 ft with its long axis oriented north-south. The moderate pitch, side gable roof was sheathed in asphalt

roll material. An approximately 8 ft deep by 40 ft long shed roof projection was located on the north end of the west elevation. A gable roofed basement bulkhead shelter still stands near the west end of the former north elevation. The damage to the building is too great to determine door and window location and type. Historic photographs indicate that there were five windows on the east (front) elevation. The south wall fell and crushed two, short, freestanding louvered air intake towers. Visible interior equipment includes a large horizontal cylinder Ingersoll Rand air compressor, Westinghouse electrical equipment cabinets, air lines, steel piping with Walworth castings, and a bank of electrical resistor grids.

The Compressor Building contained the mechanical air compression equipment for supplying compressed air for underground mine ventilation and pneumatic rock drills, and for aboveground air-driven tools and equipment. It also housed battery-charging equipment for electrically driven equipment. The building collapsed under the weight of heavy snow during the winter of 2000-2001.

Change House

The Change House is located approximately 75 ft south of the Compressor Building, at the point where the access road turns 90 degrees to the east. It is a rectangular, 64 ft long by 52 ft wide, single story building with the axis of its moderate pitch gable roof oriented north-south. The north (front) elevation contains, from east to west, two 16½ ft wide vertical plank sliding doors with an external overhead track, and two windows. The west elevation contains, from north to south, a paneled wood personnel door, a window, a concrete block chimney that rises above the eaves, and four

windows. The south elevation contains a central 30-panel wood garage overhead roll door flanked on each side by a pair of windows. Between the two east windows a square brick chimney with a concrete base and cap rises approximately 2 ft above the eaves. The east elevation contains, from south to north, a 13 ft long by 4 ft wide gable roofed basement bulkhead shelter, a square brick chimney, two windows, and a 12 ft deep by 26 ft long core rack storage shed with doors in the north and south elevations. The Change House is in good condition; however, the roofs of the basement bulkhead shelter and core rack storage shed are both collapsing.

The Change House was where mine employees signed in and out for their shifts, changed into waterproof clothing and steel-toed boots, and picked up lamps and batteries for their hard hats. At the end of their shifts miners used the showers in the Change House. Clothing and personal belongings were placed in galvanized wire baskets that were hoisted above the changing room floor on a chain that could be locked by its owner. A pile of these baskets is located in the southwest corner of the building. The building and the attached shed at the south side have more recently been used to store a collection of Elizabeth Mine exploratory drill cores, which are still in racks inside the building. These drill cores have been inventoried and examined by the U.S. Geological Survey. The east half of the building is one open area, and the west half is divided into rooms by pressed wood panel walls. Comparison with historic photographs indicates that the large sliding doors in the north elevation are a post-mining era modification, and that the north elevation originally featured, from east to west, a paired set of windows, a personnel door, and three single windows. The personnel door was surrounded by hand-painted plank signs with safety slogans on them. The

photograph indicates that at one time a small flower garden with a short white picket fence was kept along the north elevation of the building.

Drill Core Storage Shed

The Drill Core Storage Shed is located 37 ft south of and at a skew to the Change House. It is a rectangular, 24-x-12-ft timber frame structure with wood sills, a plank shed roof, and vertical plank walls. The long northwest elevation contains four pairs of vertical plank double doors. The structure has no windows. The building is in fair condition, with some walls leaning.

The Drill Core Storage Shed was originally used for drill core storage. It currently contains a mix of mining and non-mining equipment, including possible flotation tubs.

Mine Foreman's Office

The Mine Foreman's Office is located 75 ft northeast of the Change House. It is a rectangular, 12-x-10-ft, single-story building with a wood sill foundation and an asphalt roll sheathed roof. The single entrance consists of a vertical plank door in the south elevation. The building has a single window each in the west and north elevations. A brick stovepipe surround is located at the north end of the west elevation. The building contains one north-south oriented interior partition. A small shed roofed storage box is attached to the west elevation. The Mine Foreman's Office is in poor condition; its roof is partially collapsed and the walls are leaning outward. The Mine Foreman's Office currently contains stacks of empty drill core trays.

1898 Adit

The portal of the 1898 Adit is located 68 ft west of the northwest corner of the Change House. The 1898 Adit is a masonry mine tunnel portal with splayed approach retaining walls built into the east-sloping hillside. The structure is Y-shaped in plan, with a 24 ft long, east-facing vertical portal wall with a 36 ft long curving wing wall extending out from each end to the east. The portal wall is approximately 10 ft high and 2 ft thick and built of irregularly coursed flat slabs of mortared dark schist. The portal mouth is slightly narrower at the top, where a thin reinforced concrete lintel spans the entrance. The portal is blocked off with a wall of 1-inch wire mesh screen bolted to an angle iron frame. The wing walls are built of unmortared schist and mine waste rock, and curve out and slope down from the ends of the portal wall to meet the ground. The area outside the adit between the wing walls is marshy and watered by acid mine drainage, obscuring the original ground surface. The area behind the portal wall to the west has collapsed, blocking the mine entrance. A 5½ inch diameter galvanized steel compressed air pipe rises from the ground at the foot of the south wing wall, rises to the top of the wing wall, and extends southwest for several feet before disappearing into the ground. The 1898 Adit is in fair condition, with some of the sulfidic mine waste rock used in the wing walls spalling and deteriorating. Comparison with historic photographs indicates that the wing walls originally continued north and south of the portal at a height of approximately 4 feet.

The 1898 Adit was driven by the Tyson mining concerns to provide access to new ore reserves for their early-twentieth-century smelting activities. The distance from the portal to the workings at the 300 ft level in the orebody

to the west is approximately 1,400 ft. In 1942 the adit was enlarged to accommodate larger, 36-inch gauge electric mine cars, and the portal face and wing walls were entirely rebuilt using local stone. The 1898 Adit served the mine until the early 1950s. As mining progressed north and deeper by the mid-1940s, the adit became too far from the mine workings and could not efficiently handle the increasing volume of ore being mined. The 1948 Adit and Shaft were constructed further north to remedy this problem (see below). The railroad track laid on the floor of the adit emerged from the portal and split into three tracks opposite the Change House. Two dead-end spur tracks extended east for approximately 300 ft, the north one extending straight and the other one swinging to the south, to an equipment storage area. The main track swung to the north, running east of and parallel to the upper road on an embankment supported by an approximately 8 ft high schist slab retaining wall. All tracks were lined with regularly spaced steel support poles and portals for the overhead electrical mine car catenary power wires. A spur track diverged to the west and entered the Machine Shop/Workshop through a large door in its east elevation. An approximately 200 ft long parallel passing siding was located west of the main track, east of the Machine Shop/Workshop and Office/Warehouse Building. The main track proceeded east across the lower road on a steel bridge (see below) to the ore crusher plant bins. In 1948, when the new adit and shaft were completed to the north, the rail line was extended north past the crusher and curved back to the west to enter the 1948 Adit (see below). All rails and ties have been removed, and only three catenary supports survive. One is a steel pipe portal with two vertical posts and a crossbar with ceramic insulators located opposite the Machine Shop/Workshop. The other surviving catenary supports are discussed below.

Mine Equipment Dump

The Mine Equipment Dump is a scatter of large-scale mining artifacts located approximately 200 to 300 ft east of the 1898 Adit along the rights-of-way of the two mine equipment spur tracks east of the 1898 Adit. The largest object is an approximately 15 ft tall, welded sectional steel overhead gantry crane that appears to be in its original location straddling the north spur track. This structure originally had an asphalt shingle roof on top of it sheltering a chainfall. Other artifacts include an electric mine locomotive, and an ore skip car. This artifact scatter also included two large welded steel ore buckets and two spoked steel hoist sheave wheels, which were removed from the site in 2002 or 2003. Several antique truck bodies were placed around the periphery of this artifact scatter by a post-mining era landowner.

Main Electrical Substation

The Main Electrical Substation is a rectangular concrete pad located on a wooded plateau approximately 100 ft east of the Office/Warehouse Building, east of the Fuel Pumps. The dimensions of the concrete pad cannot be determined because of accumulated organic debris; however, it appears to be approximately 30 ft long by 15 ft wide. There are sawn-off telephone poles located at the corners and along the long sides, and there is a water-filled concrete pit at the south end. The Main Electrical Substation is in poor condition and retains little of its original structure or equipment. Historic photographs indicate that the transformers on the substation pad were enclosed by six vertical wood telephone poles with horizontal braces and topped by a grid of timbers supporting insulators.

A 1,200 kW, 33,000-volt utility transmission line, which entered the mine property in the vicinity of the south end of the tailings piles, served the Main Electrical Substation. At the Main Electrical Substation the voltage was stepped down to 2,200 volts and 440 volts for electric motors, and 110 volts for lighting. Transformers fed lines and cables radiating out to other substations and mine facilities including the underground workings, mine buildings, and the Ompompanoosuc River Pumphouse 1 mile north of the mine (see below).

Electrical Cable Vault

The Electrical Cable Vault is located in a wooded area at the foot of the upper road terrace, approximately 175 ft east of the collapsed Compressor Building. It is an approximately 10 ft high, 5 ft diameter, hollow cylindrical tile block masonry structure with a flat roof. It is built into the foot of the terrace, and a horizontal 3 ft square concrete cable conduit box extends from its west side into the terrace slope. Clusters of threaded steel pipes in the walls and floor contain thick insulated electrical cables that have been cut flush with the ends of the pipes. The Electrical Cable Vault is in fair condition. Recent deposition of fill on its upslope side has caused the structure to lean and crack and a steady stream of water is issuing from the cable conduit inside.

The Electrical Cable Vault is located within the footprint of the former Tyson ore concentrating mill that stood on this site from about 1900 until World War II. The vault served as an access point for buried cables between the Main Electrical Substation, and the mine buildings and underground workings to the west.

Fuel Pumps

The twin Fuel Pumps are located approximately 6 feet apart on a low rectangular concrete pad in a wooded area east of the Office/Warehouse Building, on a former roadway below the mine car track retaining wall and west of the Main Electrical Substation. Manufacturer's tags identify them as built in 1937. The pumps are square in plan with stamped sheet metal housings and glass panels over the readouts and rectangular illuminated panels above them. The pumps are decorated in a Streamlined Moderne style with vertical fluting at the corners and parallel vertical line motifs in the trim and display bezels. The hoses are still in place but the dispensing nozzles have been removed. The pumps are in fair condition, with some broken glass, and are missing their original signage.

The Fuel Pumps provided fuel for mine road vehicles. The mine owned several automobiles and trucks, including two trucks that continuously ferried copper concentrate from the mine to the Pompanoosuc Depot on the Boston & Maine Railroad approximately 10 miles east via Route 132. The pumps dispensed gasoline and also diesel fuel for heavy equipment.

Mine Car Bridge

The Mine Car Bridge carries the mine car rail tracks from the 1898 Adit over the lower road at a point between the Office/Warehouse Building to the southwest and the Concentrating Mill to the northeast. The bridge consists of substructure and superstructure elements. The substructure consists of two, parallel, skewed, poured-in-place, reinforced concrete abutments with

faces 33 ft apart. The south abutment is located at the northeast tip of, and serves as part of, a retaining wall for the northeast corner of the terrace created for the upper road and its buildings and mine car track. Where the wall intersects the ground it is 32 ft long. It is flanked by stretches of rough drywall incorporating pieces of schist and mine waste rock. The stone wall to the southeast is mostly collapsed, and the wall to the northwest 30 ft long, with the first 10 feet closest to the abutment collapsed. The north abutment is a freestanding wall with a 14 ft wide inside face and short northward flaring projections at each end. The bridge superstructure consists of two, parallel, skewed, 33 ft long I-beams built up with riveted sectional steel plate and L-stock resting directly on concrete bearing blocks that are cast integrally with the tops of the concrete abutment walls. The two parallel I-beams are laterally braced with two pieces of I-stock oriented perpendicular to the main I-beams and braced to the side of the beams with inverted diagonal C-stock brackets. A steel pipe mine car electrical catenary portal is located at the south end of the bridge. The Mine Car Bridge is in good condition, although missing the ties and rails for the mine car tracks.

Ball Mill Ball Bin

The Ball Mill Ball Bin is located immediately north of the Mine Car Bridge and 36 ft west of the Concentrating Mill on a flat terrace with a 32 ft long concrete retaining wall at its east edge. It is a rectangular open-topped structure with a massive timber frame and plank walls flanked by heavy timber trestle bents that carried the mine cars directly over its top. The bin itself measures 20 ft long north-south and 14 ft wide east-west, and its interior is lined with sheet steel with the bottom sloping steeply to the

east. It is flanked by tapering, bolted, timber frame tower bents, one to the south between the bin and the Mine Car Bridge, and three to the north of the bin. The mine car trestle bents, which extend 20 ft north of the bin, are mounted on square cast concrete bases and are braced with horizontal and diagonal planks and heavy timber lintels that supported the mine car rails. The Ball Mill Ball Bin is in poor condition, with partially collapsed walls and floor.

The Ball Mill Ball Bin was used to store the steel balls that were used as grinding media in the ball mill in the Concentrating Mill (see below).

1943 Crushing Plant

The remains of the gable roofed 1943 Crushing Plant are located approximately 60 ft north of the Ball Mill Ball Bin, immediately west of the Thickener/Filter Building. The wood superstructure has been removed and the rectangular foundation is filled with demolition debris, leaving an approximately 75 ft east-west by 35 ft north-south concrete floor and foundation with several partially visible concrete pits and piers. The mine car rail line ran along the west side of the building, where two parallel rows of tall, square, vertical, concrete trestle bent support posts run north-south across a deep gully. Mine cars ran over this trestle and dumped the run of mine ore into a large ore bin, which has completely collapsed. Immediately east of the trestle supports, the hillside is terraced with tiers of masonry drywalls of flat schist slabs that flank the primary crusher base at the west end of the building. The concrete posts and stone walls in this area are partially obscured by a conical mound of oxidized ore left over from the collapsed ore bin. The most prominent features are the two crusher

machinery bases, which consist of an arrangement of cast reinforced concrete pylons with vertical threaded steel machinery mounting pins on their top surfaces. The primary (opposed jaw) crusher base is located at the west edge of the foundation, and the secondary (cone) crusher base is located in the east part of the foundation. The crusher bases are partially buried by fallen planks and timbers.

These crushers reduced the run of mine ore to a size small enough for feeding to the ball mill for fine grinding. The equipment and processes located inside the 1943 and 1949 Crushing Plants, Concentrating Mill, and Thickener/Filter Building will be discussed in greater detail under the Ore Processing Technology section below.

1949 Crushing Plant Ruins

The 1949 Crushing Plant was located approximately 100 ft north of the 1943 Crushing Plant and approximately 75 ft east of the Assay House. The only trace of this once substantial gable roofed building is a short section of concrete wall and heavy plank ore bin exposed on the south side of a pile of oxidized ore. There is no sign of the massive concrete footings that would have supported the crusher. This building was constructed in 1949 to handle the increased volume of ore coming from the new 975 ft level.

Ore Processing Buildings: Concentrating Mill and Thickener/Filter Building

The Concentrating Mill and the Thickener/Filter Building are two large, attached buildings in the cluster of ore processing and associated buildings located northeast of the row of administrative and support buildings located

along the upper road. They are located approximately 160 ft northeast of the Office/Warehouse Building and approximately 160 ft southeast of the Assay Laboratory. These buildings, where the crushed ore was processed into a concentrated form for shipment for smelting offsite, were the heart of the aboveground technological operations at the Elizabeth Mine. The buildings no longer contain any significant mechanical equipment. These are the most massive buildings remaining at the site, and they are also among the most badly deteriorated. The roofs of both buildings have been collapsing for several years. Because of the size, condition, and irregular footprint of the buildings, and the steeply sloping hillside they are built into, accurate field measurements of some elevations of the buildings could not be made. The Concentrating Mill and the Thickener/Filter Building were framed with bolted heavy wood timbers, some 11 inches thick, salvaged from the Woodbury Granite Company stonecutting sheds in Bethel, VT, approximately 12 miles northwest of the mine. An independent exterior wall surrounded the interior framing system to isolate the exterior walls from the vibration of the mill machinery (Wheeler 2000:8-22).

The Concentrating Mill and Thickener/Filter Building are large, rectangular buildings with their long axes parallel and oriented east-west. The Concentrating Mill lies to the south and the Thickener/Filter Building is located to the north and offset approximately 50 ft to the east. The buildings are connected by an approximately 15 ft wide, one story link, and appear as two large connected masses. The Concentrating Mill is built into the toe of a steep hillside, and the Thickener/Filter building sits largely on a flat terrace at the bottom of the slope. Each has a saltbox type roof shape, with the long plane of the Concentrating Mill roof facing east and the

long plane of the Thickener/Filter Building facing west, creating two, large, opposed geometric masses.

Concentrating Mill

The Concentrating Mill is an approximately 90 ft long east-west by 58 ft wide north-south, high, rectangular building. It is built into the hillside and has a high, stepped concrete foundation and a distinctive moderate pitch saltbox roofline with a long east facing slope, which clearly express the tiered arrangement of the floors and gravity-fed process inside. The roof is supported by six longitudinal timber truss systems. Because of its condition, the original location and arrangement of entrances and fenestration is difficult to determine. The east elevation (now collapsed) originally contained several windows and a paneled wood personnel door with a bracketed gable-roofed awning. The east elevation of the 15 ft wide link connecting the building with the adjacent Thickener/Filter Building contains a pair of large, paneled wood, swinging garage-type doors with upper rows of lights. The west elevation contains openings for several windows and at least two doors, one a wide opening to the east end for a pair of swinging paneled wood doors, and another upslope to the west for a personnel door. The asphalt shingles on the east 20 ft of the elevation are slightly different in color from the rest of the building, clearly demarcating a later addition. A short, one bay, one story, rectangular, gable roofed ell (no longer extant) originally extended south from the side of the building. At the west, uphill end of the elevation, are the ruins of the crushed ore silo. This structure consisted of a circular arrangement of interlocking vertical concrete staves held together by steel rod hoops with tensioning turnbuckles, with a polygonal, asphalt single roof. The silo has collapsed, leaving a

semicircle of stave stubs on the uphill side, a pile of broken staves fragments, and a mound of oxidized ore, some of which has fallen into the building through door and window openings. A single window is centered under the roof peak opposite the silo location. Lower down, near the bottom of the wall, is a rectangular opening for a chute or conveyor.

The west elevation is dominated by a one-story, shed-roofed flotation reagent mixing room extension that is flush with the south elevation and extends north roughly two-thirds of the width of the west elevation. This windowless extension has a paneled wood personnel door in its north elevation. North of this extension is a set of diagonal plank double doors. Above this door is a second story entrance consisting of a paneled wood personnel door. This higher door was accessed by an enclosed external stairway shelter that ascended to the south and wrapped around the northwest corner of the building. The west section of this enclosed stairway has collapsed, isolating the high door. The west half of the north elevation includes the intact, first floor section of the enclosed stairway. Above it is the remains of the inclined housing that sheltered the crushed ore conveyor belt that rose from the 1943 Crusher Plant to the ore bin in the upper level of the Concentrating Mill, consisting of a short inclined housing with a gable roof extending several feet north from the wall above the stairway. East of the stairway the wall of the building projects approximately 6 feet north. This elevation contains a vertical plank personnel door surmounted by a tall, narrow, vertical opening covered by hinged doors. The east half of the north side of the building is not visible as it is attached to the Thickener/Filter Building by a short, approximately 15 ft wide one-story link with a similar sloping roof profile.

The interior of the Concentrating Mill is divided into several areas that step down in height from west to east, following the cascading process that was aided by the flow of gravity and water. The small one-story shed roofed extension on the west side of the building contains two, cylindrical, iron hoop-banded, wood stave mixing tubs with crossbeams for electric mixing motors across the tops. These tubs were used for mixing flotation process conditioners and reagents. East of this room is a taller, empty room that was used for storage of flotation chemistry drums. East of this space is the earlier fine ore bin (350 ton), a heavy timber framed bin with heavy timber support posts that extend down to the concrete mill floor. East of this is a large, open, full-height, full-width room that contains the massive concrete piers and footings for the ball mill, spiral classifier, flotation cells, and their electric drive motors. East of an interior dividing wall is another space for additional flotation cells.

The Concentrating Mill is in poor condition. The roof over the flotation sections has completely collapsed into the east half of the building, the roof sheathing has fallen into the ball mill section at the center of the building, and the east wall fell outward during the winter of 2002-2003. The asphalt wall sheathing and gyplap board underlayment are beginning to peel away from the building. The iron hoop-banded, vertical interlocking concrete stave fine ore bin has completely collapsed. A small one-story ell on the south side is no longer standing, and the enclosed inclined conveyor belt housing between the 1943 Crusher Plant and ore bin is no longer extant.

The Concentrating Mill was where the crushed ore was ground to a fine powder in a ball mill, a rotating drum full of steel balls and water. The resulting slurry was circulated through a series of flotation tanks where it was

agitated with paddles and compressed air bubbles in chemically treated water. The ore stuck to the bubbles and the concentrate was skimmed off and sent to the adjacent Thickener/Filter Building for additional processing. In 1952, a 20 ft addition was made to the east end of the Concentrating Mill for additional flotation cells for extraction of the pyrrhotite (iron sulfide) component of the ore, which was shipped to the Brown Paper Company, Inc. of Berlin, NH, for making sulfuric acid for paper manufacture.

Thickener/Filter Building

The Thickener/Filter Building is an approximately 90-x-46-ft rectangular, three-story building with a concrete foundation and an asphalt-shingled saltbox roof. The roof is supported by six longitudinal timber truss systems. The east elevation is in poor condition, with its upper floor collapsed and much of its asphalt sheathing missing. This elevation originally included four windows on the upper floor. Two horizontal rows of stub ends of the ore bin timbers protrude slightly from the wall. The north elevation of the building contains a louvered attic vent, three third story windows, and three, second story windows. The ground floor at the east end includes two, large, double leaf, diagonal plank doors that provide truck access to the underside of the ore bins. The asphalt shingles on the east 16 ft of the elevation are slightly different in color from the rest of the building, clearly demarcating a later addition. Fragments of wall and roof materials on the west half of the ground floor mark the outline of the later Pyrrhotite Processing Building that was added to the north. The wall inside the shadow of this addition contains two windows and a large rectangular opening cut into the wall. A partially collapsed stairway connecting the first and second floors is located at the west end of the north elevation.

The west elevation of the building contains two windows flanking an elevated second story entrance. The east elevation of the building contains six irregularly spaced windows on the third story. The ground floor at the east end includes two, large, double leaf, diagonal plank doors that provide truck access to the underside of the ore bins.

The interior of the Thickener/Filter Building is also divided into major spaces from east to west. The west half of the building, where the thickener was located, is an open, full-height, full-width space. The floor is occupied by a circular array of regularly spaced, vertical concrete posts that supported the extremely heavy, round, open thickener tank and its mechanical stirring equipment. Rising from the northeast and southwest corners are massive tall concrete pylons that carried the horizontal crossarm that supported the heavy rotating thickener arm and its drive motor. The tank and stirring machinery has been removed. A narrow section at the center of the building contains a scale, and an electric motor with belt drives connecting it to an air compressor and a pump. The east half of the building is occupied by two ore concentrate bins built of massive bolted wood timbers. The floor above the ore bins is an open area with a small locker room at the south end. The filters for dewatering the chalcopyrite and pyrrhotite concentrates were located in this room, above their respective ore concentrate storage bins.

The Thickener/Filter Building is in poor condition. The east (pyrrhotite) ore bin has collapsed, the roof and top floor wall on the east side of the building have collapsed. The asphalt sheathing and gyplap board underlayment are beginning to peel away from the building.

The Thickener/Filter Building housed a thickener to partially dewater and thicken the chalcopyrite concentrate slurry from the flotation tanks in the adjacent Concentrating Mill. After the slurry was thickened, the viscous pulp was run through a rotating vacuum filter to remove all but 6 percent of its moisture. The filtered concentrate was then dumped into the ore bin, and dispensed into the trucks that ferried it east on Route 132 to the Boston & Maine Railroad at Ompompanoosuc Depot on the Connecticut River in Norwich, VT. In 1952, a 16 ft addition was made to the east side of the Thickener/Filter Building for a second ore storage bin for storage of pyrrhotite (iron) concentrate, with the pyrrhotite filter located above.

Pyrrhotite Thickener Building

The gable roofed Pyrrhotite Thickener Building was located immediately north of the Thickener/Filter Building. It is a ruin consisting of an approximately 50-x-50-ft concrete foundation filled with timber demolition debris. Rising from the northeast and southwest corners are massive tall concrete pylons that carried the horizontal crossarm that supported the heavy rotating thickener arm and its drive motor. The Pyrrhotite Thickener Building was built in 1952 to house the thickener for the pyrrhotite processing. After thickening the iron concentrate was pumped to a filter and sent to the iron concentrate bin added to the east side of the Thickener/Filter building in 1952.

Flotation Tubs

Three discarded Flotation Tubs are located approximately 150 ft south of the Garage in a small cluster of trees. Each tub is a long, narrow, rectangular,

open-topped, sheet steel trough with a system of attached pipes and agitation motor brackets. These flotation tubs appear to be crude, locally fabricated units and likely date from pre-World War II-era milling in the Tyson Mill that was located immediately west of the tubs. The function of flotation tubs is discussed in the Ore Processing Technology section below.

Tailings Pumphouse

The Tailings Pumphouse is located approximately 130 ft northeast of the Thickener/Filter Building, at the foot of a gully running along the west toe of TP 1. It is a deteriorated, one-story, rectangular building measuring approximately 14 feet on each side with a north facing shed roof. A 1½- ft square wood launder (open trough) enters the south wall of the building and ends above an approximately 4 ft square plank bin with iron binder rods. A second, lower wood box flume exits from the north side of the box. This equipment appears to be a simple sediment settling box. An approximately 2 ft diameter cast iron centrifugal pump case is located in the southeast corner, near several lengths of iron pipe that have been exposed by erosion just outside the building. An electrical power pole is located at the northeast corner of the building. The Tailings Pumphouse is in poor condition, with a collapsed roof and leaning walls. The remains of several tiers of launder trestles are buried in the gully south of the building and in the west wall of the tailings pile to the east.

The Tailings Pumphouse is the only survivor of a cluster of small one story buildings located east of the Concentrating Mill and the Thickener/Filter Building that were associated with the processing and distribution of

Concentration Mill tailings. This building apparently played a role in sediment reduction as well as wastewater and/or tailings pumping.

Garage

The Garage is located east of the lower road, 50 ft south of the Concentrating Mill. It is a long, north-south oriented, 76 ft long by 25 ft wide, rectangular, one story building with a moderate pitch roof. It has a high, tiered, concrete foundation cut into the hillside to the west. The east (front) elevation contains five 30 panel wood overhead roll doors with windows in the top row of panels. The south door is slightly taller than the others. A paneled wood personnel door is located at the north end of the east elevation. The south elevation contains a square central window, the north elevation contains a rectangular central window, and the west elevation contains six evenly spaced square windows. Sash configuration is unknown as these windows are boarded up. The Garage is in good condition, although the west wall is beginning to bow out at the top.

The Garage was used for shelter and maintenance of Vermont Copper Company vehicles. At one time the company owned three dump trucks, one diesel bulldozer, two pickup trucks, and an ambulance (Condict, personal communication 2003)

Heating Plant

The Heating Plant is located 31 ft east of the Concentrating Mill and 38 ft south of the southeast corner of the Thickener/Filter Building. It is a rectangular, 20-x-24-ft building with its long axis oriented east-west. It

has a saltbox roof with its long plane facing Tailings Pile 1 to the east. It incorporates multipaneled wood doors that appear to have been reused from a late-nineteenth- or early-twentieth-century building. The north (entrance) elevation includes, from east to west, a paneled door, a storage rack with a shed roof, and a tall, square, stepped, brick chimney with a concrete cap and cast iron ash cleanout door. The chimney steps back three courses in width about half the way up, and extends high above the roofline of the building. The west elevation includes, from north to south, a window and a paneled door. The east elevation contains three windows and a small plank telephone box at the south edge. The south elevation includes, from west to east, a 3 ft deep by 12 ft long, shed roofed storage shed with three vertical plank doors and three interior shelves; a paneled door; and a window. The interior is divided into two spaces by a north-south wall. The east half is a small workshop with a workbench along the east side windows and pipe fitting storage racks along the inside west wall. The west half of the building is an excavated pit containing a small H.B. Smith Company watertube boiler. The Heating Plant is in good condition.

The heating plant provided the adjacent ore processing buildings with sufficient heat to keep process water at the proper operating temperature and also provided heat for the personnel working inside these large buildings. There is no evidence of steam lines running to other buildings; they would had to have been placed in insulated aboveground conduits to prevent freezing, and most buildings have their own stoves for heat as indicated by the chimneys. The east half of the building housed the pipefitting and tinsmith shop for the mine, where plumbing supply parts were stored and sheet metal parts were fabricated (Condict, personal communication 2003).

Fire Hose House (typical)

The Fire Hose House is located approximately 30 ft north of the northwest corner of the Thickener/Filter Building. It is an approximately 4 ft square, one-story, wood structure with vertical board and batten siding and a north-sloping shed roof. The exterior is painted red and the interior contains a simple wood hose reel. A red cast iron fire hydrant is located immediately west of the building.

There were originally several fire hose houses in the building complex, each located at a hydrant. Numerous hydrants are still located in their original positions; however, the Fire Hose House is the only surviving example of this type of structure at the Elizabeth Mine.

Assay Laboratory

The Assay Laboratory is located on the east side of the lower road, approximately 210 ft north of the Office/Warehouse Building, and approximately 25 ft west of the Lower Water Tank Building. It is a 69 ft long, 20 ft wide, rectangular, single-story building with the long axis of its front gable roof oriented north-south. The roof is sheathed in new red asphalt shingles. The south (front) elevation has been altered by the addition of a one bay by five bay shed roofed sun porch with asphalt roll roofing. The original facade has a replacement door flanked by original windows. The west elevation contains six irregularly spaced windows and a square brick chimney at the south end that projects approximately 5 ft above the eaves. The north elevation has a 12 ft square projection to its east side, which in turn has a 6 ½ ft wide, 5½ ft long projection to its east

side, and a 6 light window on its west side. The east elevation contains, from south to north, four windows, two paired short windows, a new door leading out onto a small modern deck, a blocked door, a window, and a paneled wood door. The Assay Laboratory is in good condition.

The Assay Laboratory was a vital part of mine operations. Here mine staff constantly tested samples of ore from the mine and the ore concentrate from various stages of the beneficiation process. This information was used to plan underground operations and to control the chemistry of the flotation process to maximize efficiency and copper concentrate production (Brown 2003). This building is rented by the owner as a residence and is currently inhabited.

Lower Water Tank Building

The Lower Water Tank Building is located at the south edge of the gravel parking area on Mine Road, immediately north of the fork in the access roads, approximately 25 ft west of the Assay Laboratory. It is a tall, one-story, 34-x-32-ft rectangular, gable roofed building with a 12 ft wide by 14 ft long gable roofed projection extending north from the west end of the north elevation. The west (Mine Road) elevation contains, from north to south, a paneled wood door in the north projection, and a square, boarded-up window. On the north elevation, the projection contains a boarded up square window, and the gable end of the main section of the building contains a 20 panel wood garage roll door on the ground level and a window above it. The fenestration on the east elevation is unknown as the south end is partially collapsed. The south elevation contains a paneled wood door, and a water tank level indicator gauge that hangs from the peak of the roof on the south

elevation. This feature consists of a wide vertical plank painted white with the numerals 1 through 10 painted from top to bottom in black with horizontal black lines between them. The south half of the roof of the main section of the Lower Water Tank Building is collapsed, revealing heavy, bolted timber roof trusses forming a clear-span interior. The water tank and all other equipment have been removed.

The Lower Water Tank Building originally contained a large heated tank that supplied water to the Concentrating Mill. A small furnace in the projecting wing in the northwest corner was used to keep the water from freezing in the winter. The large vertical water level indicator board on the south elevation was visible from the Office/Warehouse Building and the Concentrating Mill so that operators would know when the water level became low (Condict, personal communication 2003). A mechanical visual indicator, no longer extant, slid up and down the gauge to show the water level. The south half of the roof collapsed under the weight of heavy snow during the winter of 2000-2001, revealing the heavy timber roof trusses.

Electrical Shop

The Electrical Shop is located approximately 75 ft northeast of the Assay Laboratory, approximately 150 ft east of Mine Road. It is a rectangular, 29 ft long north south by approximately 12 ft wide east west, one by five bay, timber frame structure with a saltbox roof with the long plane facing east and a wide, bracketed awning sheltering the open west side. A vertical plank door is located in the west elevation. The interior contains a variety of wood storage racks. The structure is in poor condition, is leaning to the north, and is missing its roof sheathing. It is built on a steep hillside

and supported underneath by tall wood posts. A mine car catenary support pole is located 12 ft southwest of the building, and consists of a vertical steel pole topped by a bracketed horizontal pole with a hanging ceramic insulator.

The Electrical Shop is located immediately east of the mine car rail line leading to the 1948 Adit, located approximately 200 ft northwest at the east edge of Mine Road. It was used to store electrical equipment for lighting and power transmission inside the underground mine workings that could be loaded on mine cars as they passed the structure.

Copper Castle

The Copper Castle is an occupied residence located on the west side of Mine Road, approximately 225 ft west of the Office/Warehouse Building and approximately 250 ft southeast of the Upper Water Tank Building foundation. It is a rectangular, approximately 40-x-30-ft, 2½-story residence with a fieldstone foundation, clapboard siding, a side gable, corrugated metal roof, and overhanging eaves. The east (front) elevation and roof have been extensively modified with the addition of a full-length porch and paired shed dormers lighting the attic and shed roofed wall dormers lighting the second floor. Windows consist of a mix of original, six-over-six, double-hung, wood sash and replacement one over one units. Trim consists of soffit and fascia boards, and plank cornerboards and window surrounds. An original narrow central brick chimney rises from the center of the roof, and an external square cinderblock chimney is located on each side gable wall. The full-length front (east) porch is illuminated on all three sides by a continuous band of six-over-one windows.

The Copper Castle dates from the mid-nineteenth century, when it served as a dormitory for mine workers. It also served as a two-family tenement during the mid-twentieth-century period of operations (Condict, personal communication 2003).

Upper Water Tank Building foundation

The Upper Water Tank Building foundation is located on the east slope of Copperas Hill, west of Mine Road, approximately 400 ft west of the Lower Water Tank Building. It is located immediately northeast of a north-pointing hairpin turn on a gravel driveway located behind the Copper Castle. The building has been removed, leaving a roughly 35-x-35 ft flat poured concrete slab.

Like the Lower Water Tank Building, the building at this site contained a heated tank for Concentrating Mill process water and had a water level indicator board on its east gable end that was visible from the Office/Warehouse Building and the Concentrating Mill.

1948 Shaft Site: Hoist House foundation, Idler Tower ruin, and Headframe/Shaft Collar site.

The 1948 Shaft Site is located on the east slope of Copperas Hill, west of Mine Road, approximately 400 ft west of the Lower Water Tank Building and approximately 100 ft north of the Upper Water Tank foundation. It consists of three north-south-oriented elements spaced equidistantly over a distance of approximately 230 ft. These are, from south to north, the Hoist House foundation, Idler Tower site, and the Headframe/Shaft Collar site.

The Hoist House foundation is a flat concrete slab measuring approximately 24 ft wide north-south and at least 30 ft long east-west, with its west edge buried by soil from the slope above it to the west. The foundation is obscured by organic debris with some features still visible. The most visible feature is the base for the cable hoist motor and drum, a raised, 14-x-14-ft, concrete-walled pit with a rectangular motor mount pier in the southeast corner and the cable drum pit to the west. The southeast corner of the foundation contains a raised transformer platform consisting of a grid of steel I-beams cast into the floor. Several threaded steel pipes with cut electrical cables are located inside and outside the foundation at this corner. Immediately north is an approximately 3 ft square pit surrounded by a raised U-shaped concrete lip with its north end open. The foundation has several additional vertical steel pipes with cut cables protruding from the floor. The superstructure of the hoist house has been removed, leaving the complex concrete foundation exposed. The building was similar in construction to the other World War II-era buildings, with a saltbox roof. This building contained the electrically driven hoist for the 1948 Shaft, which consisted of a large electrical motor connected by a reduction gear drive to a large-diameter drum wound with thick woven steel wire rope that ran out through apertures on the north end of the building, over the Idler Tower and Headframe, and down into the mine shaft. The hoist-powered cables were for two of the three vertical shaft compartments, one for men and equipment, and one for raising ore. The third compartment carried air, water, and electrical utility lines. One cable wound on the underside of the Hoist Drum and the other was wound from the top towards the opposite end. Therefore when an ore shed was being hoisted up in one compartment of the shaft, a man-cage or equipment cage was going down in the second compartment, serving to counterbalance one another.

The Idler Tower was a truncated, pyramidal, square plan structure built of bolted square creosoted timbers with diagonal X-braces. It is now a ruin consisting of a pile of rotting timbers connected by threaded wrought iron rods with washers and nuts. The Idler Tower originally supported a cluster of mine hoist cable guide pulleys that kept the cables from sagging and stretching, which accelerated wear; from tangling in high wind; and it assisted in guiding the cables as they wound around the drum.

The Headframe/Shaft Collar site consists of two features, the capped shaft collar and the headframe back brace footings. The Shaft Collar is a low, raised, 21 ft long east-west by 9½ ft wide north-south, hollow, reinforced concrete structure with a flat, 1 ft thick, 19½ ft long by 8 ½ ft wide concrete slab safety cap containing a cluster of three, short, 4 inch diameter vertical threaded steel pipes from which issues a strong upward draft. The Shaft Collar was the liner for the top of the three compartment shaft that met the 1948 Adit. Each of the two headframe back brace footings is located 37 ft south of the corners of the south side of the Shaft Collar. Each consists of a half-buried, truncated, pyramidal, 2½ ft square, concrete footing inclined to the north with a 2 ft by 15 inch steel plate with three bolt holes cast into the north facing side. These plates are the anchors for the south-sloping timber headframe tower back braces. This tower, taller than the idler tower, was a bolted timber 4-post framework that was divided into three panels by horizontal bracing with diagonal cross bracing. The top of the tower supported a cluster of two spoked steel sheave wheels, or pulleys, that guided the cable over the top of the tower and down into the shaft. The sheave wheels and the vertical part of the tower below them were protected by a gable-roofed enclosure that also kept the elements out of the

mineshaft. The cables entered this shelter through two small apertures on the south side.

The 1948 Shaft was sunk in 1948 to meet the 1948 Adit at the 300 ft level. As noted above under the 1898 Adit, by 1948 that sole underground mine entry had become too distant and shallow an access point to efficiently mine the northward and downward trending orebody. After the mine was closed in 1958, the hoist equipment was removed, the idler tower and headframe were dismantled, and the shaft collar was capped with a concrete slab.

Infirmary/Carpenter Shop

The Infirmary/Carpenter Shop is an occupied residence located north of the core mine complex, on the west side of Mine Road, approximately 225 ft north-northwest of the Lower Water Tank Building, and approximately 175 ft south of the Club House/Boarding House. It is T-shaped in plan, with a 40-x-18-ft, rectangular, four bay by three bay, 1½-story main section with a regular pitch, front gabled, asphalt-shingled roof, and a rectangular, 40-x-18 ft, five bay by two bay, one-story, shed roofed addition extending to the south. All windows are replacement one-over-one, double-hung sash units. The east (front) elevation of the main section of the building has a plank door flanked on each side by a window, with paired windows under the gable on the second story. The north elevation contains, from east to west, two windows, a door, and a window. A short, narrow brick chimney rises from the center of the roof ridge. The addition is offset 8 feet west from the front of the main section of the house, and its shed roof slopes down to the west. The east elevation contains five irregularly spaced windows, and the south elevation contains a modern door and a single window. The west elevation

contains four windows. The Infirmary/Carpenter Shop has recently been sensitively restored and is in excellent condition. The entire building sits on a recent concrete foundation.

The construction details of this building suggest that it was built in several stages. The east half of the north section appears to be the oldest section, possibly dating from the mid-nineteenth century. The west half and the ell to the south appear to be subsequent structures. A 1950s photograph shows only the east half of the north section, with a one-story, shed roof shed where the west half is today. The northern end of the building was used as an infirmary and the south ell was used as a carpenter shop during the mid-twentieth century mining period (Wheeler 2000:8-22).

Boarding House/Club House

The Boarding House/Club House is an occupied dwelling located north of the core mine complex, on the east side of Mine Road, approximately 175 ft north of the Infirmary/Carpenter Shop. It is a rectangular, 38 ft long north-south by 28 ft wide east-west, 1½-story wood frame structure with a side gable, asphalt shingle saltbox roof with overhanging eaves and a narrow central brick chimney. The building is in excellent condition, but lacks historic integrity. The house has been moved east, away from its original location closer to the road, and placed on a new poured concrete foundation. The gable roof has been modified into a saltbox by changing the angle and raising the eave height of the east (rear) roof plane. The building has all new clapboard siding, new doors, and many new triple windows. The original entrance in the west (street) elevation has been replaced with a small window, and the main entrance moved to the south elevation inside a 20-x-11-

ft shed roofed sun porch addition with large single pane windows and sliding glass doors on the south elevation. A rear basement door opens onto a terrace on the east side of the building. A 32 ft long north-south by 12 ft wide east-west fieldstone foundation is built into the slope south of the building, and is the foundation for a large wing, no longer extant.

This building as shown in early-twentieth-century photographs had a symmetrical gable roof with minor applied ornamentation in the form of several small Italianate roof brackets. A large gable roofed wing, approximately the same size as the main block of the house, extended from the south elevation, offset to the east. This section of the building was later destroyed by fire. This building was used as a boarding house during nineteenth- and early-twentieth-century mine operations, and as a social gathering place during mid-twentieth-century operations.

Community Center and Federal Housing Site

The Federal Housing Site is located on the west side of Mine Road, approximately 1,000 ft north-northwest of the Lower Water Tank Building. The site is a large open rectangular, sloping area containing three broad man-made terraces separated by long, narrow rows of trees. These terraces were the location of four parallel rows of long, narrow multiple-family units, no longer extant. The original layout consisted of a figure eight driveway with two long, narrow dwellings located end-to-end on the upper terrace to the southwest above the upper roadway, two pairs of similarly arranged dwellings inside the upper roadway loop to the northeast, and one row of two dwellings inside the southwest side of the lower roadway loop further northeast. Today only the northwest and southernmost roads survive as the driveway for the

Community Center, which is located at the southeast corner of the complex, at a 45-degree angle to the orientation of the terraces.

The Federal Housing Site was completed in 1943 at a cost of $175,000 to provide 40 apartments for miners and their families. The long multiple-family units were insulated and had central heating, electric lights, running water, and sewage disposal. The units varied from two rooms and one bath to five rooms and one bath. All had modern kitchen equipment. Rents varied from $23.00 to $29.00 per month. The site was selected and laid out to provide every building with a view of the White Mountains to the east and to provide room for a victory garden for each unit (Jacobs 1944:13; Randolph Herald 1943b).

One domestic structure, the Community Center, is located at the west edge of the former Federal Housing Site. The Community Center is a long, narrow, rectangular, 63 ft north-south by 25 ft east-west, five bay by two bay, side-gabled building with a concrete foundation, vinyl clapboard and vertical siding, and a shallow-pitch, raised seam metal roof. The southwest (rear) of the building is irregular in plan and incorporates a series of rectangular gable roofed projections for utilities and a rear entrance. The front (southeast) elevation entrance consists of a replacement door under a gable-roofed projection with square columns and a short flight of concrete steps. The building has been moderately altered with the addition of replacement windows, including a large picture window in the northeast elevation, and glass sliding doors in the southeast elevation. The building has two brick chimneys, an original internal one located near the intersection of the main section and the rear projections, and a later external stepped and corbelled one at the southeast end of the southwest elevation. A small garden shed is

located immediately to the west, and a larger storage building is located approximately 300 ft west of the house.

The Community Center was built as part of the Federal Housing complex to serve as a recreational facility for miners living in the adjacent rows of dwellings to the north. It was equipped with games and a radio (Jacobs 1944:13). It also served as a Catholic chapel for the miners (Wheeler 2000:8 22). The Community Center is the only surviving building from the Federal Housing complex and is currently an occupied residence.

Ompompanoosuc River Pump House

The Ompompanoosuc River Pump House is located on the south bank of the Ompompanoosuc River, approximately 2,000 ft north of the northwest corner of TP 1, and approximately 1,400 ft southeast of the intersection of Rte 132 and Furnace Road. Although it is an outlying building, its construction and appearance are the same as the buildings in the core mine complex to the north. The building is a ruin with its collapsed walls lying on top of remaining electrically powered pump equipment. The foundation appears to measure approximately 25-x-25 ft and the location of the entrances or windows cannot be determined because of the condition of the building. The foundation is partially constructed on the old concrete foundation of the farther, smaller Heckscher era pumphouse.

The Ompompanoosuc River Pumphouse was an important component of the materials handling networks at the Elizabeth Mine. It was the primary source of clean process water for the Concentrating Mill. The facility was not regularly manned, although it was linked to the core mine site by a roadway. The pumps

were electrically powered and a row of utility poles carried the electrical lines between the substation at the mine and the Pumphouse. The water was pumped about 3,000 feet south and 250 feet uphill in an uninsulated 6-inch diameter pipe to the Upper and Lower Water Tank buildings, from which it was gravity fed to the Concentrating Mill below (Condict, personal communication 2003).

Air Vent

The Air Vent is located on the south side of the Ompompanoosuc River at Furnace Flats, approximately 300 ft south of the Air Shaft (see below). It is an approximately 12 to 18 inch diameter vertical steel pipe connected to the underground mine workings. The interior is heavily encrusted with mineral deposits and the original diameter cannot be determined. The pipe rises several inches above the surface of the ground and has a flange with bolt holes around the outside edge. The pipe emits a strong, steady flow of water from the underground mine workings that has precipitated an apron of whitish-orange aluminum and iron oxides on the west terrace of the Ompompanoosuc River. Downstream of this deposit, the rounded boulders and cobbles in the riverbed are stained orange with the metallic oxides.

The Air Vent was a churn drill hole installed to provide ventilation to the underground mine workings. The Air Vent, and the Air Shaft and Ompompanoosuc River Electrical Substation (see below) are surface expressions of the northern extent of underground mining of the Elizabeth Mine orebody in the mid-1950s when mining had progressed north of the West Branch of the Ompompanoosuc River. A second air vent pipe is located to the south on private property between the Air Vent and Mine Road.

Air Shaft

The Air Shaft is located on the north side of Route 132, approximately 400 ft northwest of Furnace Flat Road and 14 ft south of the Ompompanoosuc River Electrical Substation (see below). It is located on a rock outcrop approximately 10 ft north of the shoulder of the road. It is a 7½ ft square, approximately 4 ft high, hollow, reinforced concrete structure, capped by a steel sheet and a 6 inch thick cast concrete slab. The slab has recently been cut and a locked steel hatchway door installed in the steel plate. There is approximately 10 ft of water below the cap and a second concrete slab sealing the shaft below. A cluster of threaded steel pipes with cut electrical cables is located in the west side of the north face, closest to the Ompompanoosuc River Electrical Substation.

The Air Shaft was added to the mine workings in the mid-1950s when mining had progressed north of the West Branch of the Ompompanoosuc River. The shaft is approximately 195 ft deep and is inclined slightly to the south. It included a ladder to the workings that was installed as an emergency exit.

Ompompanoosuc River Electrical Substation

The Ompompanoosuc River Electrical Substation is located on the north side of Route 132, approximately 400 ft northwest of Furnace Road and 14 ft north of the Air Shaft. It consists of a 12 ft long by 5 ft wide, low, rectangular concrete pad with a vertical steel pole with a horizontal steel crossbar with ceramic insulators rising from the south end of the pad. The pad is protected by a high galvanized chain link perimeter fence located five ft out from the pad. The fence has an inward-swinging chain link gate in the east

elevation with a wood plank sign bearing the words "DANGER HIGH VOLTAGE" written in block letters. A similar sign is mounted on the south side of the fence, and one reading "DANGER 2300 VOLTS" is mounted on the north side. The Ompompanoosuc River Electrical Substation is in fair condition. All transformers and electrical gear have been removed.

The Ompompanoosuc River Electrical Substation provided electricity for lighting and mine locomotives at the north end of the workings that had progressed north of the Ompompanoosuc River by the mid 1950s.

Major Mid-Twentieth-Century Mine Landforms

Mining activity in the World War II to 1958 period created new industrial landscapes and altered preexisting ones. These landscapes can be divided into two classes: those associated with mining ore from surface deposits in an effort to increase the mill capacity at the beginning of operations, and deposition of ore milling waste throughout the period of operation.

The surface workings are located south of the mine buildings, along and west of Copperas Road, which diverges from the west side of Mine Road approximately 1,000 ft south of the entrance to the main mine building complex. The South Open Cut and North Open Cut are linear surface excavations along major exposures of the north south trending ore deposit. These long, narrow openings are in stratified rock that dips approximately 70 degrees to the east, leaving a steep west footwall and overhanging east hanging wall. The exposed sulfide rock and discarded ore in and around the edges of the cuts has decayed to a bright yellow earth that is mostly barren and supports only pine, birch and other acid-tolerant plant species.

South Open Cut

The South Open Cut is an approximately 1,600 ft long, 100 ft wide, 75 ft deep, north-south oriented, excavated rock trench located approximately 3,500 ft southwest of the core mine buildings, approximately 300 ft west of Copperas Road (Figure 21). The southern third of the South Open Cut is dry, and the northern two-thirds hold bright green water. The water in the cut drains to the east through a perpendicular truck haulage crosscut trench located approximately 600 ft north of the south end. The main trench is approximately 20 ft deep at the south end, and increases in both depth and wall height to approximately 75 ft to the north. At the north end of the cut a large tunnel extends north for approximately 160 ft. A small passageway extends from the roof of the tunnel to the North Open Cut. Just north of the north lip of the South Open Cut is an approximately 5 ft square concrete-capped shaft that connects to the tunnel below. There is evidence of recent major rock falls from the footwall into the cut. North of the crosscut one major rockfall has divided the watered section into two separate pools, the south one approximately 22 ft deep and the north one approximately 14 ft deep. Approximately 500 ft east of the truck haulage crosscut, east of Copperas Road, is a truncated conical pile of rock excavated from the crosscut.

The ore at the site of the South Open Cut cropped out on the surface and was explored in a series of prospect pits, still visible at either end of the cut. Exploratory drilling in the early 1940s indicated the size and shape of the deposit. By the late 1940s the Vermont Copper Company was exploiting several sources of ore to increase throughput in the Concentrating Mill. Starting in 1949 the South Open Cut was drilled and blasted from the surface.

A small steam shovel was used to load dump trucks that entered and exited via the crosscut and took the ore north on Copperas Road to be processed. Water flow into the cut was a problem and pumps were set up to keep it dry. Excavation work was not conducted during the winter months. Excavation ended in 1953 when the bottom of the ore deposit became too narrow to excavate with the steam shovel.

Copperas Works Site and North Open Cut

The Copperas Works site is an approximately 12-acre area located approximately 800 ft north of the South Open Cut and 2,000 ft south of the entrance to the core mine buildings (Figure 22). This area was largely associated with copperas (iron sulfate) mining and manufacturing from 1809 to about 1882, and also with contemporaneous and subsequent copper mining (Kierstead 2000). This area includes the North Open Cut on its west edge, and consists of a steep, east-facing slope containing yellow piles of oxidized ore, red and black piles of roasted and leached ore, and timber and masonry remains of copperas works infrastructure. The North Open Cut was excavated for copperas ore and averaged several dozen feet deep when the works closed in 1882. North of the North Open Cut is an area associated with copper ore mining by the Tyson family between 1882 and 1890. This area was originally covered with thick heaps of copper ore that was considered low grade by 1880s standards.

In the late 1940s the North Open Cut and Tyson mining area were both sampled and exploited as sources of ore to increase throughput in the Concentrating Mill. The North Open Cut was greatly expanded. The hanging wall was cut back to allow safe mining from the surface, and the low-sulfide waste rock

was deposited along the east edge of the cut, overlying the earlier copperas works roast beds. The orebody was also stoped out from below from the 300 ft level, and mined out to within 10 feet of the floor of the cut. The dump ore at the Tyson mining area, along with similar material from the Ely Mine, was run through the Elizabeth Concentrating Mill. It was difficult to efficiently process because it was oxidized, which interfered with proper performance of the flotation reagents.

The North Open Cut is an approximately 1,000 ft long, 100 ft wide, north-south oriented, excavated rock trench located just east of the ridge of Copperas Hill. The cut is shallow at its south end, but quickly plunges in depth to the north. The lip of the west, footwall rises higher than the lip of the east, hanging wall, and is bordered by birch woods right to its lip. The west, dead end of an earlier adit or crosscut forms a pocket in the footwall, which is now occupied by a large bird's nest. The bottom of the pit is not visible in places, and several transverse pillars of rock remain in place, creating arches that span the walls. The north endwall contains three large cavernous openings and two, smaller ones, stopes where mining followed the shape of the orebody underground to the north. Rock has fallen into the cut, making it wider and shallower. The Tyson mining area to the north is an irregular expanse of yellow oxidized ore and weathered purple-brown lumps of solid ore. A whitish, bleached-looking area is evidence of a dump rock fire.

Tailings Piles 1 and 2

Tailings piles 1 and 2 (TP 1 and TP 2) are massive piles of Concentrating Mill tailings that were pumped into the Copperas Brook valley in the area

east of the core mine buildings between 1943 and 1958 (Figure 23). These tailings piles consist of finely ground material occupying a wedge-shaped area with its wide end to the north and its tapering end pointing to the south. This triangular area is approximately 2,000 ft long north-south and 1,400 ft east-west at its north edge. TP 1 to the north is the larger, lower of the two, and TP 2 is smaller and located above and to the south of TP 1. Both tailings piles have moderately sloping sides, and top surfaces that appear flat but actually slope gently to the south for drainage. TP 1 has an approximately 150 ft high, 1,400 ft long north slope, which wraps around to the west side of the pile overlooking the ore processing buildings. TP 2 is located at the southwest corner of TP 1, and measures approximately 500 ft by 450 ft, with an approximately 75 ft high northeast face overlooking TP 1 to the north. The east side of TP 1 and the east and west sides of TP 2 do not have sloping escarpments, but instead blend into the hillside topography.

The piles were formed by planned disposal of pulverized rock and pyrrhotite ejected from the mill after all of the marketable components of the ore had been removed. The tailings piles were built by classifying the homogenous tailings slurry from the Concentrating Mill into coarse sands and fine slimes, and pumping them in pipes to a system of wooden troughs, or launders. The coarse sands were used to build up dams at the perimeter of the piles, and the fines were pumped into the area behind the dams, which were engineered to slope gently to the south to draw off the water. A dewatering system consisting of buried segmental concrete culvert pipes and segmental concrete decant towers was installed to drain the water into Copperas Brook. The majority of TP 2 was deposited after 1952 when pyrrhotite began to be extracted from the tailings.

Since the mine closed in 1958 the appearance of the tailings piles has changed. The ground rock and pyrrhotite were originally dark gray to black when freshly deposited. An outer layer of the tailings less than a yard thick has weathered to a tan-orange color. The sloping faces of the piles have eroded into small, parallel vertical gullies, giving them a corrugated appearance. Chemical weathering has also accentuated the horizontal stratigraphy of the pile, revealing layers of slightly different shades of color. The top of TP 1 was barren until 15 or 20 years ago, when the property owner spread organic debris over the northwest half of the top of the pile. This area is now overgrown with coarse grasses and small tree saplings, greatly reducing the size of the expanse of bare orange ground. Birch saplings have also begun to encroach on the top of TP 2. In 1973 a flood washed out a deep gully near the southeast end of the dam at TP 2, exposing the segmental concrete pipes for the decant system. Copperas Brook now runs out from this gully into a braided stream on top of TP 1 that feeds a shallow pond at the southeast edge of the pile. The remains of the wood trestles that supported the launders are visible as linear configurations of regularly spaced wood pole stumps on the flanks of the piles.

ORE MINING AND PROCESSING AT ELIZABETH MINE, 1943-1958

Underground Mining Operations

Mining operations at the Elizabeth Mine during the 1943-1958 period drew on three sources of ore. In descending order of importance and volume, these included fresh ore from new underground workings, fresh ore from surface pits, and oxidized ore from old ore dumps. Surface excavation from the pits and dumps has been discussed above. The underground orebody was long and tabular, shaped like a distorted plank with an average width of 15 to 20 ft with swells up to 60 ft. It was as much as 400 ft tall, but generally less than 200 ft tall, and pinched considerably in places. North of its outcrop at the North Open Cut, it descended belowground north for approximately 7,000 ft at a shallow angle of between 15 to 20 degrees, and plunged east at a dip angle of between about 60 and 80 degrees. The linear, northward sloping orebody was mined from a series of longitudinal horizontal drifts (tunnels), or levels, that provided access to long, north-south oriented stretches of ore that was mined by two main methods so that the ore blasted from overhead was fed by gravity to mine cars running along the drifts below. Eventually mining encountered barren rock at the north and south end of a level and the northward progression of mining required access at increasingly deeper points. In profile the levels are arranged in an overlapping, *en echelon* fashion as the orebody progresses deeper and to the north. The underground levels were referred to by their depth in feet descending from the 0 ft level, the surface outcrop at the North Open Cut.

In 1942, U.S. Bureau of Mines reported on the existing underground conditions at the Elizabeth Mine, which reflected all mining activity to that date

(Figure 24). The sole underground entrance to the mine was via the 1898 Adit, which was measured at 1,360 ft long. This adit led west to the 300 ft level, where a shallow angled inclined shaft or slope, extended down at an angle of 25 degrees for 830 ft northeast following the eastward plunge of the orebody, intersecting and serving the 400 ft level, 500 ft level, and 600 ft level. The overall length of mined ground on the strike north and south of the adit was approximately 2,500 ft, with approximately 1,800 ft of that north of the adit. The 300 ft level had been driven north and south of the adit. To the south the level was driven about 825 ft to a point just south of the north end of the North Open Cut above. The ore above the level had been stoped (excavated) out to a distance roughly 500 ft south of the adit, with the rest of the drift to the south undeveloped. The stoped out area included the area mined from the vertical shafts sunk by the Tysons in the 1880s. North of the adit ore was also stoped out above the 300 ft level for approximately 300 ft. The winze descending from the 300 ft level intersected the 400 ft level approximately 150 ft north of the adit. The 400 ft level extended approximately 375 ft south from the intersection under a stoped out area into unmined ground with two raises to the 300 ft level. North of the intersection the 400 ft level extended approximately 350 ft under a funnel shaped area stoped out above. The winze continued down and north another 300 ft to the 500 ft level, which was driven through approximately 250 ft of unmined ground to the south and approximately 300 ft of partially stoped ground to the north. Finally, after descending another 250 ft the winze bottomed out at the 600 ft level, which extended north through approximately 800 ft of unmined ground. It was estimated that about 320,000 tons of ore had been mined from these workings prior to 1942 (USBM 1942:6, 1943:8).

When mining resumed in 1943 the sole access to the orebody was through the 1898 Adit, which was straightened and widened for 36-inch gauge overhead catenary electric mine cars, and had a 2.25 percent outbound grade. The 100, 200, 300, 400, 500, and 600 ft levels were prepared for working by clearing a cavern for a work station at the end of the 300 ft level adit and installing a 250 hp electric hoist to pull ore skips up the inclined shaft, which was widened for 42 inch track, with double track to the 500 ft level. Ore was hoisted from loading pockets on the 400, 500 and 600 ft levels in 4 ton ore skip cars. By 1944 mining activity consisted of cleaning and enlarging the stopes (areas of ore blocked out for mining) above the 300 ft level south and in the vicinity of the 1898 adit and in the 300 and 400 ft levels north of the inclined shaft. More intensive mining took place on the 500 ft level, where the area above the inclined shaft was partially stoped up and blocked out to the roof of the orebody. The 500 ft level was driven 800 ft north where it ran into barren rock. No work was done on the 600 ft level (Figures 25 and 26). Ventilation was provided by a fan on the 300 ft level (Jacobs 1944:6; USBM 1943:9).

During the second half of the 1940s development work progressed in several directions (Figures 27 and 28). The 300 ft level was driven south to a point just north of the middle of the North Open Cut above. A new 575 ft level was driven south from the inclined shaft to explore "Ore Shoot No. 2," a new lens of ore discovered below the main orebody. On the 600 ft level, approximately 650 ft north of the foot of the winze, a new, 400 ft deep, two compartment winze was sunk through the orebody at an angle of 63 degrees east to the 975 ft level, intersecting the barren rock at the bottom of the orebody. This facilitated exploration and development of the 725, 850, and 975 ft levels north and south of the new winze (Benson et al. 1950:20).

By 1948 tramming and hoisting ore almost 2,000 ft from the north end of the 600 ft level and up to the 300 ft level had become uneconomical and inefficient. New ore reserves containing 10,000,000 lbs. of copper had been mapped out north of and below the 600 ft level and plans were made to mine it via the 975 ft level. In 1948 a new vertical shaft was sunk in the hanging wall of the orebody about 1,100 ft north of the 1898 adit, and a new adit was driven 400 ft west to meet the shaft at the 300 ft level, 100 ft below its ground level collar. The mouth of the new adit was located just north of and above the new mill buildings, east of Mine Road. The 300 ft level at the new and old adits was not connected underground. The new shaft infrastructure was designed to handle workings 3,000 ft deep. The surface plant consisted of a 4-post timber headframe built of 8-inch Douglas fir posts with 10-inch square backbraces. The headframe supported two 6-foot diameter sheave wheels mounted 40 ft above the collar. The hoist house was 228 ft south of the collar. The hoist was a 72-inch by 94-inch, single grooved-drum unit with 16,800 lbs of pull running at 100 feet per minute (fpm) with 1-1/8-inch wire rope. The manufacturer of this unit is unknown. It had a manual brake with a Simplex safety controller. The hoist was driven by a 250 hp, 2200 v, 60 cycle, 3 phase, 720 rpm induction motor. The rectangular shaft measured 17 ft 8 in X 6 ft 4 in. It contained three, 5 ft square timber-lined compartments: a cageway for men and large pieces of equipment; a skipway for the ore skip that doubled as an emergency manway; and a utility shaft for water and air pipes, and electrical cables. The ore skip held 4 tons, or about 60 cubic feet of ore (Benson et al. 1950:20-21).

From the point where the 1948 Adit intersected the new shaft at the 300 ft level, the shaft then descended another 675 ft to the 975 ft station, where a horizontal tunnel extended west for approximately 900 ft to the orebody at

the 975 ft level (Figure 29). A shallow sloping crosscut was also driven 200 ft up to the southwest from the 975 ft station to access the 575 ft level. The 975 ft Station consisted of a loop tunnel excavated in the rock around the shaft that included rails for mine cars, D.C battery charging stations, an electric motor-generator set, and a water sump and pump. Mine cars loaded with ore coming from the orebody at the 975 ft level proceeded east on 24-inch gauge tracks to the loading pocket where the self-dumping Graney-stlye cars discharged the run of mine ore onto a grizzly (grate) with 22 x 16 inch openings located above a 250 ton ore pocket excavated from the rock. Mine skip cars were loaded at a loading station below the ore pocket for the trip up to the 300 ft level where the ore was dumped into electric mine cars for the trip east to the 1948 Adit portal and thence aboveground to the crusher. On the 975 ft level ore cars and mine locomotives could also take a switch that led to the battery charging stations and to the cage compartment at the shaft. The shaft contained two sumps, one 12,000 gallon sump below the 575 ft level, and one 66,000 gallon sump below the 975 ft level. Each was equipped with a 450 gpm Pomona pump. The mine made an average of 30 gallons per minute (gpm) of water. Electricity at 2,200 volts was brought to substations on the 575 ft and 975 ft levels, where transformers stepped it down to 440 volts. Compressed air was delivered in 6-inch mains, and water in 2-inch mains. Ventilation was provided by a 3 ft, 25 hp Aerodyne fan with 35,000 cubic feet per minute (cfm) capacity at 3 inches vacuum. The fan was located at the bottom of the 1948 Shaft at the 975 ft level and blew air up the shaft (Benson et al. 1950:20-21).

The new shaft and underground haulageways allowed significant increases in ore production and by February 1950 the extent of underground development had progressed dramatically (Figure 30). Almost all the remaining ore in the

zone between the area north of the North Open Cut and the bottom of the inclined shaft at the 600 ft level had been stoped out above the winze. On the 300 ft level south of the 1898 Adit, additional stoping took place above the drift in a 300 ft long zone 550 ft south of the adit. On the 400 ft level, all the ore in a zone 550 ft south of the winze was stoped out. The 575 ft level had been developed, with a drift extending south from the old winze approximately 900 ft to an approximately 600 ft long stope in Ore Shoot No. 2, with raises to the 400 ft and 300 ft levels. The 575 ft drift was continued another 1,100 ft to explore the lower reaches of an indicated "Ore Shoot No. 3," but ran into barren ground. Stoping had begun north of the bottom of the winze at the 600 ft level. Mining had also progressed from the new winze connecting the 600 ft level with the 975 ft level. On the 725 ft level a drift had been driven approximately 300 ft south of the winze and ore had been stoped out for approximately 400 ft north of the winze. On the 850 ft level a drift was driven approximately 100 ft south of the winze and ore was stoped out to a point approximately 700 ft north of the winze. On the 975 ft level a drift had been driven approximately 700 ft south. A raise was driven up to the south to access the 850 and 725 ft levels, and a winze was sunk down from above, all with the goal of exploring ground in a deeper section of Ore Shoot No. 2. The new winze was only used for access to the 725 and 850 levels (Benson et al. 1950:20).

In 1950 ore was still brought out through both adits. The 1898 Adit handled production from the south end of the mine only, and the 1948 Adit handled all production from the mine below the 300 ft level. By 1953 exploratory drilling on the 975 ft level revealed an approximately 2,000 ft long parallel ore bed approximately 150 ft west of the main orebody, beginning at a point approximately 1,300 ft north of the 1948 shaft and extending to beneath the

Ompompanoosuc River. This orebody was mined via a crosscut located approximately 3,000 ft north of the 1948 shaft. At this time production was split between three major zones, with 200 tons of ore per day coming from the South Open Cut, 200 tons from workings south of the 1898 Adit, and 400 tons coming from workings below the 300 ft level and north of the 1948 Shaft. Eight separate underground areas were being stoped simultaneously. After 1953, ore was no longer mined in the south workings and no longer exited the mine via the 1898 Adit (Benson et al. 1950:20; Brown, personal communication 2003; Lutjen and Kearney 1953:72-73).

By 1954, mining south of the 1948 Shaft on the 300 ft level had progressed almost 1,600 ft south of the 1898 Adit to a point about two-thirds of the way south under the North Open Cut, a pair of raises had been driven up, and stoping had begun (Figure 31). This drift facilitated stoping the remaining ore under the floor of the North Open Cut. On the 575 ft level, additional stoping in the upper part of Ore Shoot No. 2 brought workings up almost to the floor of the 300 ft level in a 1,000 ft long zone that extended north and south of the previous stopes. Mining at this location had begun on the lower section of Ore Shoot No. 2 that had been previously explored via a southward extension of the 975 ft level. The 975 ft level was drifted approximately 900 ft south of the 1948 Shaft and three raises were driven up to the lower part of Ore Shoot No. 2, which was stoped out 600 ft along plunge to the south, with a raise driven up to the 575 ft level. The most dramatic progress was made north of the 1948 Shaft. The 975 ft level was driven another 2,000 feet, to a point 3,100 ft north of the 1948 Shaft, approximately 500 ft south of the Ompompanoosuc River, with a sublevel above it driven even farther north. The ore was stoped out above the level for a distance of 2,800 ft north of the 1948 Shaft, with a raise at the 1,700 ft

mark driven up into the roof of the orebody and a sublevel extended approximately 500 ft south and about 700 ft north (McKinstry and Mikkola 1954:4).

When the mine closed in 1958 underground mining had been conducted almost 7,800 ft along strike from the south end of the North Open Cut to a point 1,600 ft north of the Ompompanoosuc River (Figures 32 and 33). Approximately 2,900 ft of this work was undertaken south of the 1948 Shaft, and approximately 4,900 ft of it took place north of the 1948 Shaft. South of the 1948 Shaft the 300 ft level was driven almost 1,900 ft south of the 1898 Adit to the south end of the North Open Cut, where a raise connected to the 200 ft level, the surface, and a tunnel south to the South Open Cut. The ore under the North Open Cut was completely stoped out to within 10 feet of the floor of the North Open Cut. South of the 1948 Shaft, the 725 ft, 850 ft, and 975 ft levels were all drifted south to meet the lower section of Ore Shoot No. 2 that had been partially mined out by 1954 via the southward extension of the 975 ft level. The 600 ft long section of ore along the plunge of Ore Shoot No. 2 was stoped up under the floor of the 575 ft level. Again, the most dramatic progress was made north of the 1948 Shaft. No more work was done in the 350 ft long zone north to the new winze, or on the 600 ft, 725 ft or 850 ft levels north of the winze, which were completely stoped out. North of the new winze, the orebody was stoped for approximately 4,600 ft to a point 1,600 ft north of the West Branch of the Ompompanoosuc River. The roof of the mine was approximately 195 ft below the riverbed. Approximately 200 ft north of the river a 200 ft deep inclined Air Shaft (combination manway and utility shaft) was sunk on the workings, and an Electrical Substation was also installed at the surface. Mining at this great distance from the main shaft required improvements in ventilation. At the

north end of the 975 ft level two churn drill holes were sunk on the workings for air vents and each one was equipped with a 15 hp, 7,500 cfm blower. These include the Air Vent at the Ompompanoosuc River. Total ventilation through the main shaft was 35,000 cfm, with 12,000 cfm coming through the south workings and the rest from the north. The mine was drained by one sump at the 975 ft level with a 75 hp pump rated at 350 gpm pumping an average of 125 gpm of water from the mine (Lutjen and Kearney 1953:72-74).

Underground Mining Methods

The stopes, the areas of ore above the level drifts that were blocked out for mining, were removed, or drawn, by two primary systematic methods, sub-level stoping, and shrinkage stoping. At the Elizabeth Mine, one method was preferred over another at different times and depending on underground conditions.

In 1943 the mining method in use was "subleveling" at 20 ft intervals with slot raises 100 ft apart (USBM 1943:9). The term "subleveling" is synonymous with sublevel stoping (Figure 34). Sublevel stoping (or subleveling, sublevel benching, or bench system) was developed in Michigan iron mines in 1902. It is a relatively low-cost method of extraction that is appropriate in ore deposits that like the Elizabeth Mine, are physically strong, of uniform value, and with firm walls in steeply dipping beds. Ideally the access shaft is sunk outside the orebody. A horizontal crosscut is made to the orebody, and longitudinal drifts are driven along the length of the orebody, either in it or just outside it in the footwall, depending on the strength of the ore and its conforming rock. To prepare a stope for subleveling, inclined shafts called raises are put up from the longitudinal

haulageway into and to the top of the orebody at regular intervals of 100 ft or more. Then these "blocks" are further subdivided into horizontal levels (sublevels) by drifts. Funnel-shaped drawholes are then blasted in the roof of the bottom level, or haulageway, at regular intervals under the subleveled ore in each block. A grizzly screen is installed at the bottom of each funnel. Miners then successively blast and jackhammer the ore, working from the bottom up, moving horizontally along the sublevels, benching each sublevel from above and retreating horizontally across the block so that the upper sublevels overhang the lower ones insuring safe fall of broken ore to the chute level below. This method of ore supplies a constant flow of freshly broken ore to the chutes. The ore spills through the grizzly screens onto the floor of the haulageway where it is loaded for transport to the shaft and out of the mine (Peele 1941 10/178-186). This loading is accomplished by several means using a variety of equipment, described below.

Sublevel benching arrangements can be configured with a second horizontal drift above the main haulageway level, below the row of chutes under a block of ore. This intermediate drift, called a 'scram drift," is equipped with an electrically powered scraper, called a slusher, which is essentially a wide blade attached to a cable and winch. The system is easily set up and moved within the drift. The blade scrapes the ore along the length of the scram drift to loading chutes at the raises driven between the blocks, where it drops to mine cars on tracks in the main haulageway (Peele 1941:10/191). This method was later employed at Elizabeth Mine.

In 1944 the mining methods were described as the "bench system and shrinkage stoping" (Jacobs 1944:8). This suggests a combination of the method described above and shrinkage stoping. Shrinkage stoping is another method

of ore removal that is appropriate for an orebody with the characteristics of the Elizabeth Mine (Figure 35). Primary access to the orebody via shaft, crosscut, and drift levels is similar. In shrinkage stoping the levels are sometimes prepared with chutes blasted in the roof of the haulageway, however, timbered roofs and openings are also common. A working area is cleared above the chutes, and drilling and blasting progresses upward, with overhanging ore removed in benches, retreating to either end of the block. The miners stand in the space on top of the broken ore, accessed by timbered raises from the haulageway. The ore increases in bulk when broken, and between 30 percent and 50 percent of the ore is withdrawn from the chutes as mining advances upward, maintaining a steady flow of ore and a consistent workspace for the miners above. Although shrinkage stoping is relatively inexpensive to develop, the method requires extra breaking in the mine, resulting in dilution of the ore from spalling of barren wall rock, and suffers from a lack of flexibility in the face of varying orebody configuration (Peele 1941:10/274-276, 297). Additionally, a large portion of the ore accumulates in the stope and is not drawn until the stope is mined out. This is a disadvantage as this ore oxidizes in place, interfering with the flotation process downstream.

In 1950 "Shrinkage stoping [which] had always been employed for ore production . . . was changed over to sublevel benching as rapidly as could be done . . ." (Benson et al. 1950:19). This change included the scram drift arrangement described above. This was done "to avoid the high cost of draw-hole preparation and the breaking of considerable waste . . ." Sublevel benching also eliminated "the necessity of breaking outside the ore limits to prevent muck [broken ore] from hanging up in narrow sections" (Benson et al. 1950:19). This change also reduced the time that fresh ore was exposed to

the air, eliminating the difficulties of processing oxidized ore by flotation in the Concentrating Mill (Benson et al. 1950:20). The sublevel benching process was conducted as follows: "In preparing a stope above a haulageway for benching, chute raises are put up on approximately 250 ft centers. Air operated arc gate chutes are installed and a scram drift is driven 12 ft above the back of the haulageway. Grizzlies of 90 lb rail spaced at 12 inch openings are installed above the chutes. Manway raises are driven from the haulage drift to the scram drift near the chute to the level above directly over each chute. From these raises subdrifts are driven to divide the block into benches approximately 30 ft in vertical measurements. The scram drift is slashed to the full width of the ore and 3 by 15 ft draw holes separated by 10 ft pillars are driven on the footwall. These are connected above the level and the ore is slashed to full width. Benching is done with 62-lb jackhammers drilling 10-ft holes" (Benson et al. 1950:20-21).

In 1953 the shorter orebodies were mined by shrinkage stoping, and shrinkage plus sublevel benching was used for higher ones (Lutjen and Kearney 1953:73). This combined process was described as follows: "The orebody is undercut and mined high enough by shrinkage to empty the bottom of the block. The stope is drawn and benching started. Preferably, ore is extracted at drift-level draw points, but scrams and scrapers may be used." Alternatively, "Sublevel benching using a scram drift and slushers is the alternate mining method. At present, this method is only used where the ore is found an excessive distance [12 to 20 feet] above the drift." The vertical raises dividing the blocks were placed at 170 ft intervals, and horizontal subdrifts were driven 35 ft apart (Lutjen and Kearney 1953:73-74).

Underground Mining Equipment

As early as 1944 the underground mining process was described as "highly mechanized" with electrically powered slushers and muckers (Jacobs 1944:8). In 1950 the haulageways on the 300 ft level and 575 ft level were equipped with 36-inch gauge rail and 4-ton electric trolley locomotives pulling 54 cubic ft capacity side-dump ore cars. The ore was dumped from the chutes and loaded into the cars by two men operating a compressed air powered Eimco 21B "mucker" or loading machine. This machine was a small loader with a bucket that scooped up the ore in front of it and threw it back over the machine into the ore cars. The 975 ft level had 24-inch gauge rail and 29 cubic foot capacity rocker cars pulled by a 1-ton Mancha electric tram locomotive. These cars were loaded from chutes, by scrapers via chutes, or by Eimco 21B muckers depending on the location and configuration of the workings. In 1950, "practically all muck [was] scraped to chutes by electric slushers of 20, 35, and 45 hp pulling 42 to 60 inch scrapers" (Benson et al. 1950:20). By 1953 mucking machines were preferred to scrapers as the former had a better than 2 to 1 advantage in terms of tons per man shift of ore loaded (Lutjen and Kearney 1953:74). In 1953 ore on the 300 ft level was hauled to the crusher by a 6-ton Granby electric locomotive. The 2,000 to 4,000 ft haul on the 975 ft level proved too long for the slow 1-ton Mancha locomotives. These units took the ore halfway from the working faces toward the shaft to a point where a 3 ton Titan locomotive picked them up for a fast haul to the 975 ft station. Plans were in the works for a 39 hp diesel to be moved from the south end of the mine to the 975 ft level to increase haulage capacity (Lutjen and Kearney 1953:74).

Ore Concentrating Operations

Once the run-of-mine ore emerged from the adits on the mine cars or arrived from the dumps or pits by truck, it had to be concentrated in a milling process. The ore averaged about 2 percent copper in the form of particles of chalcopyrite, with the rest of it pyrrhotite (iron sulfide) and waste rock, or "gangue." The object of the milling process was to separate the chalcopyrite particles to produce a concentrate rich enough for economical shipment for offsite smelting at the Phelps-Dodge smelter at Laurel Hill, Long Island, NY. Starting in 1952 a portion of the pyrrhotite was also recovered.

The milling process included four major operations: crushing, fine grinding, flotation, and dewatering. The concentrating equipment, processes, and practice at Elizabeth Mine were typical for their time. All rotating and reciprocating equipment was driven by electric motors. Construction of the ore processing buildings began in late fall of 1942 and processing began in September 1943 on a 200 ton (ore) per day basis (Benson et al. 1950:22). The mill as originally designed was intended to have a capacity of 500 tons per day. The concentrating process underwent several changes when the volume of ore increased after 1948 and when pyrrhotite was concentrated as a by-product beginning in 1952. The following detailed discussion of the concentrating process begins with a description of the entire plant as set up in 1943, and then covers the changes made to the crushing, flotation and dewatering steps made to accommodate additional ore and for production of pyrrhotite concentrate. The process as first conducted in 1943 was described in the 24th Report of the State Geologist on the Mineral Industries and Geology of Vermont (Jacobs 1944) (Figure 36) and in an article in the Randolph, VT,

newspaper (Randolph Herald 1944). Subsequent descriptions of process evolution include an article in Mining Congress Journal (Benson et al. 1950) and Engineering and Mining Journal (Lutjen and Kearney 1953). Additional information was obtained from oral interviews conducted in 2003 with former Elizabeth Mine clerk Jim Condict, assayer Charlie Brown, and crusher and flotation mill worker Everett Linton.

Crushing

Run-of-mine ore measuring less than 18 inches emerged from the 1898 Adit in self-dumping mine cars pulled by a small electric locomotive. The cars entered a gable roof shelter on the trestle above the 1943 Crushing Plant and dumped the ore into a timber-framed 75 ton capacity ore bin immediately east of the tracks. The ore was fed by gravity into the 1943 Crushing Plant to the throat of the primary crusher, an 18-x-36-inch Traylor, Blake-type jaw crusher. This type of crusher consists of two vertical opposed steel plates, one fixed and one moving, that form a V-shaped jaw with a linear aperture at the bottom through which material passes via gravity and is crushed to the size of the smallest aperture (Taggart 1945:4/1-20) (Figure 37). At the Elizabeth Mine the pass size was variously indicated as less than 3.5 inches or less than 5 inches. The crushed ore fell onto a 24-inch wide conveyor belt and passed under a suspended electromagnet that picked up any "tramp" iron waste that could damage the equipment downstream. The ore then fell onto an inclined, 5-x-10-ft Allis-Chalmers motorized vibrating screen with a 5/8-inch mesh (Figure 38). The undersize material that passed through the screen dropped onto a 24-inch wide conveyor belt that extended south from the east end of the 1943 Crushing Plant and rose in a gable roofed housing to the Concentrating Mill, where it was dumped into an internal, timber framed fine

ore bin described variously as holding 350 or 500 tons of ore. The oversize material "scalped" off the top of the screen was fed by a conveyor belt to the secondary crusher, an Allis-Chalmers 636R Hydrocone cone-type unit. This type of crusher consisted of a large fixed cast iron funnel with a rotating conical spindle in its throat (Figure 39). The surfaces of the funnel and spindle were sheathed with special steel alloy plates. The ore fed to the funnel was crushed finer and finer as gravity pulled it past the rotating spindle, and the minimum distance between the cone and spindle dictated the size of the material passed by the crusher (Taggart 1945:4/21). At Elizabeth Mine the cone crusher pass size was variously indicated as less than 5/8 or 3/4 of an inch. The crushed ore passed by the cone crusher was conveyed back to the vibrating screen for rescreening (Jacobs 1944:10; Randolph Herald 1944).

Fine Grinding

The crushed ore in the Concentrating Mill ore bin was gravity fed onto a 24-inch conveyor belt with a built-in scale that weighed the ore fed to the ball mill. The ore was fed at a controlled rate into a 6 ft diameter by 9 ft long Marcy grate-type overflow ball mill. This unit consisted of a rotating horizontal steel cylinder that was driven by an electric motor and reduction gear drive (Figure 40). The drum was lined with special alloy steel plates. It was filled with ore, water, and steel balls at a constant, predetermined rate, and the tumbling action of the balls ground the ore to a fine consistency. Fine grinding or comminution breaks down the ore until particles of the copper minerals desired (chalcopyrite in this case) are liberated or freed from the gangue or waste minerals (quartz, talc, and pyrrhotite). The tumbling action eroded the grinding balls, and fresh ones

were constantly added from the Ball Mill Ball Bin at a calculated rate. As the pulp was discharged, fresh water and ore was added (Taggart 1945:5/1-10). At Elizabeth Mine, the ball mill could hold 25 to 30 tons at once, was powered by a 400 horsepower motor, rotated at 19 revolutions per minute, was charged with steel balls described as 2 inches or 3 inches in diameter, and ground the ore to 200 mesh or finer. Water was added to maintain a discharge of 75 percent solids in the ground ore pulp (Jacobs 1944:10; Randolph Herald 1944).

The ore pulp discharge from the ball mill was gravity fed to a 72-inch Wemco simplex (single spiral) spiral classifier to separate the finely ground ore ready for flotation from the coarser material that had to be reground. The spiral classifier worked on the mechanical principle of hindered settling. It consisted of an inclined, rotating Archimedes screw tightly set into a long narrow tub into which the ore pulp was fed (Figure 41). The agitation action of the screw, which turned at 6 rpm, allowed the fine ore particles to float and pass over the top edges of the tub, while the coarser, sandy material sank to the bottom and was dragged up to the head end of the tub by the rotating screw blade and discharged into the ball mill for regrinding (Taggart 1945:8/1-15). The fine ore pulp from the spiral classifier was next pumped to the flotation process (Jacobs 1944:10; Randolph Herald 1944).

Flotation

By the 1940s the flotation process was the leading separation process for metallic ores. The advent of flotation in the early twentieth century is considered the birth of modern mining as it allowed the exploitation of thousands of formerly uneconomic, low-grade ore deposits. Flotation relies

on the affinity of certain finely ground mineral grains for bubbles floating on top of water that is agitated and treated with specific chemicals, or flotation reagents. By the 1940s froth flotation had emerged as the main type of flotation. In this process a pulp of ¾ water and ¼ fine ore plus flotation reagents is added to long, rectangular metal tubs where it is agitated by motor-driven paddles. Bubbles of air introduced to the bottom of the tub rise and the ore mineral particles cling to them and are skimmed off the top. The finely ground waste material falls to the bottom of the tub and is drawn off. The ore particles that overflow at the top are referred to as "heads," and the waste material or "underflow" collected at the bottom is referred to as "tails." In most cases neither are separated thoroughly on the first pass, and the heads and tails are recirculated in a series of closed circuits in flotation tubs called roughers, scavengers, cleaners, and recleaners until heads of sufficient concentration are produced (Taggart 1945:12/1-18, 52-55). At Elizabeth Mine all flotation tubs were of the Agitair patent (Figure 42). These consisted of a rectangular, rubber-lined, metal trough, subdivided into square compartments, by transverse partitions with slotted openings connecting the compartments. Each compartment had overflow inlet and outlet weirs, air inlet pipes running at 1.25 psi, and an agitator consisting of a motor-driven vertical shaft with an arrangement of baffles at its bottom end (Taggart 1945:12/71-72).

At the Elizabeth Mine Concentrating Mill, the pulp from the classifier was pumped through a 6-inch Wilfley motorized sand pump to a conditioner tub with four, 48-inch cells without separating baffles where it was thoroughly mixed with flotation reagents. The pulp flowed over a weir in the last cell and flowed into a rougher tub with four, 48 inch square divided cells connected in series by overflow weirs. The tails from the roughers were pumped through

a 4-inch Wilfley sand pump to the scavenger tub containing eight 48-inch cells. The tails from the scavengers went to the tailings pile. The heads from the scavengers were pumped back into the conditioner cells with a 4-inch Wilfley sand pump. The heads from the roughers, assaying about 8 percent copper, were pumped via a 2-inch Wilfley sand pump to the cleaner tub, which consisted of four 36-inch square divided cells. The tails from the cleaners were pumped back through a 4-inch Wilfley pump to the conditioners for reprocessing. The heads from the cleaners, assaying about 20 percent copper, went to the adjacent four-cell recleaners via a 2-inch Morris pump. The tails from the recleaners went back to the cleaners for reprocessing. Finally, the heads from the recleaners, now assaying about 24.5 percent copper, were pumped via a 2-inch Wilfley pump to the adjacent Thickener/Filter Building for dewatering (Jacobs 1944:10-11; Randolph Herald 1944).

Tailings were mechanically classified into coarser "sands" that were pumped in pipes to long wooden launders on stilts (Figure 43) to build up dams at the leading edge of the tailings piles, and the finer "slimes" were pumped behind the dams (Figure 44) and dewatered through a system of segmental concrete pipe decant towers and buried culvert pipes.

Dewatering

The heads from the last (recleaner) flotation cells, containing 40 percent solids, were pumped to a Dorr thickener, which was the machine used in the first of two steps for dewatering the concentrated ore pulp. The Dorr thickener is a mechanical discharge gravity-type thickener consisting of a wide, shallow, cylindrical tank with a slowly rotating, spiral-shaped rake

arm suspended from a beam resting on pylons at opposite sides of the tank (Figure 45). The rotation action of the rake arm combined with the addition of chemical reagents accelerates the sedimentation and flocculation of the chalcopyrite grains suspended in the slime, reducing the amount of excess water. The thickened pulp, containing approximately 75 percent solids, is pumped out of a central discharge outlet at the bottom of the tank (Taggart 1945:15/1-15). The Dorr Thickener at the Elizabeth Mine was variously described as 40 feet or 49 feet in diameter and 10 ft high, and consisted of a wood stave tank banded by circumferential steel hoops. This massive, heavy tub was supported by a dense network of concrete piers. The concentrate was pumped via a 2-inch Wilfley sand pump to the dewatering filter, located in the upper level of the Thickener/Filter Building. The thickened slime was then fed to a 12 foot long by 12 foot diameter Oliver continuous-type filter (Figure 46). This unit consisted of a horizontal drum with a finely perforated surface that rotated on a horizontal axis through a tub containing ore concentrate. The hollow space inside the drum was under a vacuum, which caused the damp concentrate to cake and stick to the sides of the drum, extracting remaining moisture from the ore. The dried cake was scraped off by a stationary blade (Taggart 1945:16/1-6). At the Elizabeth Mine, the filter left a product with 6 percent moisture. The Oliver filter was located directly above the timber framed 250 ton chalcopyrite ore concentrate bin, and the dried ore fell directly from the filter into the bin (Jacobs 1944:10-11; Randolph Herald 1944). In 1944 the mill was operated three shifts a day, except Sundays, and required 14 men to run it. Only 9,000 tons of ore a month were milled at that time. Between 93 and 95 percent of the copper in the ore was being recovered (Jacobs 1944:12)

1948: Increased Ore Capacity

By 1947 the volume of ore passing through the Elizabeth Mine ore processing plant had increased to 425 tons per day, and in 1948 the new 1948 Adit and Shaft were developed to open up access to new ore to the north on the 975 ft level. In 1949 and 1950 the Vermont Copper Company trucked a total of 60,000 tons of Ely dump ore for milling at the Elizabeth Mine, and also milled the dumps from the 1880s Tyson Elizabeth Mine mining activities. In 1949 the South Open Cut was started and worked seasonally until 1953. The throughput of the processing plant was raised to 500 tons per day at the start of 1949, however, the increased volume of ore required an increase in ore processing capacity, and therefore, new equipment, in several departments. New processing machinery and infrastructure was installed to increase capacity to 750 tons per day of ore to handle the volume from the new sources (Figure 47).

The increased volume of ore required a larger primary jaw crusher, which also allowed for less secondary blasting underground and in the open cuts, which reduced labor and explosives costs. In May 1949 work began on a new primary jaw crushing plant, which was completed on July 4. A new railroad siding and 125 ton coarse ore bin were built north of the 1943 Crusher Plant. The new bin had a 22-inch grizzly, or screen, that rejected pieces of ore larger than 22 inches, which were broken by sledge hammer. The bin fed a 10 foot by 40 inch apron feeder that dropped the ore into a new 25-x-40-inch Blake-type jaw crusher in a small building immediately southeast of the new ore bin. The crushed ore was then elevated to the interior of the 1943 Crushing Plant in an inclined, enclosed, gable-roofed conveyor. The crushed ore was dropped on a new, 3-x-4-ft vibrating screen with a 2-inch mesh. The minus 2-inch

undersize product went straight to the original screen above the 1943 cone crusher (now crushing to a ¾ inch feed size), with the undersize from that screen proceeding to the Concentrating Mill ore bin, and the oversize feeding into the recirculating cone crusher circuit. The oversize scalped off the top of the new screen went to the original 1943, 18-x-36-inch jaw crusher, through the original screen, and to the ore bin or the cone crusher depending on its size. The ¾-inch crushed ore from the Crushing Plant was elevated to the Concentrating Mill on the original 1943 conveyor. It bypassed the old 350 ton interior fine ore bin and was dumped in a new 1,500 ton, cylindrical, concrete stave fine ore bin located just outside the south wall of the mill. The extra ore storage capacity in the new 1,500 ton silo allowed mining to be cut back from six days a week to five, and crushing to be cut from seven days to six (Benson et al. 1950:22).

In the Concentrating Mill the flotation circuit was enlarged and reconfigured to handle the additional input. The new system included four 60-inch conditioner cells, ten 48-inch rougher cells, three sets of four 36-inch cleaner cells, and ten 48-inch scavenger cells arranged in new circuits for increased copper recovery. Capacity was raised within the capabilities of the existing Marcy ball mill. The Wemco spiral classifier was described as a 78-inch double pitch duplex (two spiral) unit, which was a more effecent replacement of the earlier unit, a 72-inch simplex classifier. The extra flotation cleaner tubs allowed a higher percentage of copper to be saved in the flotation process, and by 1953 mill capacity was up to 800 tons per day. The filter was described as a 6 foot, two disc unit, indicating that the Oliver drum filter had been replaced by a unit where the ore was collected on both sides of a pair of rotating hollow discs rather than on the outside surface of a drum (Figure 48). This machine provided more filtering surface

and therefore more throughput capacity (Benson et al. 1950:19-22; Lutjen and Kearney 1953:72; Taggart 1945:16/11-14).

1952: Pyrrhotite Extraction

The iron sulfide mineral pyrrhotite made up anywhere from 25 percent to 75 percent of the concentrating mill feed, and averaged 35 percent (Benson et al. 1950:22). Prior to 1952 this potential iron/sulfur commodity was pumped to TP 1; however, in that year the Vermont Copper Company began to extract 1/3 of the pyrrhotite, about 25,000 tons per year, for shipment to the Brown Paper Company in Berlin, NH, for manufacturing sulfuric acid.

Separation of this new iron by-product required additions to the flotation circuits as well as installation of a separate thickener, filter, and ore bin (Figure 49). A 20-ft addition was made to the east end of the Concentrating Mill to accommodate the new flotation equipment. A second, eight-cell scavenger was added to the primary copper circuit. The pyrrhotite process treated the tails from the second of these scavenger cells. These tails were run through an iron conditioner tub, and then into an eight-cell iron rougher tub. The tails were pumped to TP 2 (this second tailings pile was started to handle tailings from the pyrrhotite separation process, which were higher in fine mica and talc slimes that had a lower angle of repose when wet). The heads from the iron rougher went to a four cell cleaner tub. The tails were recirculated back into the cleaner, and the heads were sent to a new Dorr thickener in the 1952 Pyrrhotite Thickener Building immediately north of the Thickener/Filter Building. The diameter of the new thickener is unknown, but the size and distance between the flanking concrete pylons for the rotating arm are comparable to those for the chalcopyrite thickener. The thickened

pyrrhotite concentrate was conveyed via an SLR sand pump to an Eimco filter located above a new 16-foot wide timber framed ore bin built east of the original 1943 chalcopyrite concentrate bin. It is unclear whether this was a drum or disc type filter. The copper concentrate filter was noted as made by "American," suggesting a disc-type unit. The mill required 23 men to operate it in 1953 (Lutjen and Kearney 1953:75; Taggart 1945:16/11).

CONCLUSION

The Elizabeth Mine had a long history of operation from 1809 to 1958, and was an important source of copperas (iron sulfate) during the mid-nineteenth century. Copper production efforts, which did include several important technological "firsts," consisted of repeated efforts to apply new technology to make a known large source of copper profitable.

The 1942-1958 period of development under the Vermont Copper Company and its successor, Appalachian Sulphides, Inc., clearly demonstrates the application of typical mid-twentieth-century underground copper sulfide ore mining methods and ore processing and concentrating equipment in response to changing copper prices, contracts, and market conditions; volume and tenor of ore; and the metallurgical challenges of selectively floating copper and iron sulfide ores. The mining methods and mill equipment were changed during this period to allow the mill to reach its projected capacity and to generate a saleable pyrrhotite by-product. The increased raw ore production from new aboveground and underground sources in the late 1940s required installation of new equipment. These changes included a new, larger primary crusher and reconfiguration of the crushing circuit. Corresponding changes including larger crushed ore storage facilities, additional flotation cells, and a new

filter, all provided for additional capacity. The additions and changes to the flotation circuit also increased the percentage of copper recovered. Economic, geological, and metallurgical considerations also influenced the way the ore was mined underground. After 1952 installation of pyrrhotite concentrating equipment resulted in two distinct materials flows including new flotation cells, thickener, drier, and concentrate bins. These changes in milling equipment influenced the basic layout and continuity of expansion of the mill buildings, and even of the landscape, as TP 2 is a product of the pyrrhotite extraction campaign. Ultimately the matching and tuning of equipment and exploitation of the iron byproduct resulted in efficiency and profitability for the Elizabeth Mine.

This mining and milling activity left a group of distinctive buildings that clearly express their function in their shape, layout, relationships, and transportation connections. The technological landscape extends to the shafts, adits, and pits that were the sources of ore, and also to the tailings piles, which are also complex structures resulting from ore beneficiation and selective deposition. The architecture, infrastructure, and landscape at the Elizabeth Mine are all evidence of the complexity and magnitude of the efforts to profitably extract copper from the sulfide ores of Orange County, Vermont.

SOURCES OF INFORMATION/BIBLIOGRAPHY

A. Engineering Drawings

(NOTE: No original engineering drawings from the Vermont Copper Company, Inc., or Appalachian Sulphides Company, Inc., have been found to date).

B. Historic Views

1943 photograph of 1898 Adit at official opening of Elizabeth Mine (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

Coarse tailings being deposited on tailings pile dam, ca. 1940s. Photograph by Richard H. Little. The Elizabeth Miner, Strafford Historical Society, Strafford, VT.

Electric mine car tramline looking north, after 1948 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

Mine plant looking northeast across Tailings Pile 1, showing tailings pipelines, after 1948 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

North Open Cut looking north before 1949 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

Mine plant looking west, ca. 1950 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

Electric mine car locomotive with driver, ca. 1950 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

Mine plant and Tailings Pile 1 looking northeast after 1952 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

Cable shovel in South Open Cut, ca. 1950-1953 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

Mine plant looking northwest from Tailings Pile 2, 1962 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

Mine plant looking west from Tailings Pile 1, with Concentrating Mill, Thickener/Filter Building, and Heating Plant at center, 1962 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

Mine plant looking southwest from Tailings Pile 1, 1962 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

C. Interviews

Brown, Charlie. May 2003, South Strafford, VT. Former Elizabeth Mine Assay Laboratory employee.

Condict, Jim. May 2003, South Strafford, VT. Former Elizabeth Mine administrative employee.

Johnsson, Johnny. April-August 2003, telephone interviews. Mining engineer and historian (Finksburg, MD).

Linton, Everett. May 2003, South Strafford, VT. Former Elizabeth Mine crusher operator, flotation operator, and miner.

D. Bibliography

1. Unpublished Sources

Abbott, Collamer M.

1964 Green Mountain Copper (Long Version). Unpublished manuscript, Special Collections, Bailey-Howe Library, University of Vermont, Burlington, VT.

Ford, Ben, Matthew A. Kierstead, and Suzanne G. Cherau

2003 Historic/Archaeological Mapping and Testing, Elizabeth Mine Site, Strafford and Thetford, Vermont, Volume I. Prepared for U.S. Army Corps of Engineers, Concord, MA. Prepared by PAL, Pawtucket, RI.

Kierstead, Matthew A.

2000 Historical Context and Preliminary Resource Evaluation of the Elizabeth Mine Site, South Strafford, Orange County, Vermont. Report ADL 70939. Prepared for Arthur D. Little, Inc., Cambridge, MA. Prepared by PAL, Pawtucket, RI.

2003 Historic Industrial Landscape Documentation of the Elizabeth Mine, South Strafford, Vermont. Aerial and terrestrial Kodachrome color slide documentation. Prepared by PAL, Pawtucket, RI. Prepared for U.S. Army Corps of Engineers, Concord, MA.

Kierstead, Matthew A., Ben Ford and Suzanne G. Cherau

2003 Historic/Archaeological Mapping and Testing, Ely Mine Site, Vershire, Vermont, Volume I. Prepared for U.S. Army Corps of Engineers, Concord, MA. Prepared by PAL, Pawtucket, RI.

Smith, Gwenda

2000 Copperas Hill and Copperas Production Processes. Documentation Gathered by Gwenda Smith, with Introductory Comments on the Historic Significance of the Site. Unpublished manuscript, April 2000.

Wheeler, Walter

2000 "Standing Structures." pp. 8 22 in Statement of Site Limits, National Register Eligibility, and Potential Resources in the Proposed APE, Elizabeth Mine, South Strafford, Vermont. Report HHA #V095. Prepared for Arthur D. Little, Inc., Cambridge, MA. Prepared by Hartgen Archaeological Associates, Inc., Putney, VT.

2. Published Sources

Benson, C.B., H.A. Wangaard, and H.A. Johnson

1950 "Elizabeth Mine Reorganized for Efficient Production." Mining Congress Journal. July 1950, pp. 18-23.

Bunyak, Dawn

1998 Frothers, Bubbles, and Flotation: A Survey of Flotation Milling in the Twentieth-Century Metals Industry. National Park Service, Intermountain Support Office, Denver, CO.

Doll, Charles J, Wallace M. Cady, James B. Thompson, and Marland P. Billings

1961 Centennial Geologic Map of Vermont. State of Vermont. On file at Vermont Division for Historic Preservation, Montpelier, VT.

Hoffman, H.O.

1913 General Metallurgy. McGraw-Hill Book Company, New York, NY.

Howard, Peter F.

1969 "Geology of the Elizabeth Mine, Vermont." Economic Geology 5:3-73, Vermont Geological Survey and Department of Water Resources, Montpelier, VT.

Jacobs, Elbridge C.

1918 "Progress in Copper Mining and Milling." Report of the State Geologist on the Mineral Industries and Geology of Vermont 1917-1918. Montpelier, VT.

1944 "The Vermont Copper Company, Inc." Chapter in Report of the State Geologist on the Mineral Industries and Geology of Vermont, 1943-1944, Twenty-fourth of this series. Free Press Printing Co., Burlington, VT, pp. 1-41.

Johnsson, Johnny

2001 "Vermont's Elizabeth Copper Mine: The Tyson Years, 1880-1902." Mining History Journal, 2001, pp. 42 65.

Lutjen, George P., and John H. Kearney

1953 "New Life for Vermont's 160-Year-Old Copper Mine." The Engineering and Mining Journal Vol. 154, No. 10, October 1953: pp. 72-75.

McKinstry, Hugh E., and Aimo K. Mikkola

1954 "The Elizabeth Copper Mine, Vermont." Economic Geology Vol. 49, No. 1, Jan-Feb 1954, 1-30.

Peele, Robert, editor

1941 Mining Engineers' Handbook, Third Edition, In Two Volumes, Vol. 1. John Wiley & Sons, Inc., New York, NY.

Randolph Herald

1940 "Copper Mining at South Strafford." Randolph Herald, Randolph, VT.

1942 "Copper Boom in Orange County." Randolph Herald, Randolph, VT.

1943a "Road to be Done Sept. 1." Randolph Herald, Randolph, VT.

1943b "Homes Project Outlined for Copper Mine." Randolph Herald, 20 May 1943, p. 40 (includes map: "Plot of Buildings and Facilities at Elizabeth Mine and Copper Concentrate Processing Plant Now in Operation at South Strafford").

1944 "Vermont Copper Company's Big Mining Enterprise Now Well Established at South Strafford, VT." Randolph Herald 14 Dec 1944.

Richards, Robert H., and Charles E. Locke

1925 A Text Book of Ore Dressing. McGraw-Hill Book Company, New York, NY.

Seal, Robert R., Jane M. Hammarstrom, John F. Slack, Edward M. Hathaway, William P. Lovely, and Matthew A. Kierstead

2001 "Introduction." Environmental Geochemistry and Mining History of the Massive Sulfide Deposits in the Vermont Copper Belt (Jane M. Hammarstrom and Robert R. Seal II, eds.) Guidebook Series Volume 35, Society of Economic Geologists, Littleton, CO.

Slack, John F., Terry W. Offield, Laurel G. Woodruff, and Wayne C. Shanks III

2001 "Geology and Geochemistry of Besshi-Type Massive Sulfide Deposits, Vermont Copper Belt." Environmental Geochemistry and Mining History of the Massive Sulfide Deposits in the Vermont Copper Belt. Editors Jane M. Hammarstrom and Robert R. Seal II. Guidebook Series, Volume 35, Society of Economic Geologists, Littleton, CO.

Staley, W.W.

1949 Mine Plant Design. McGraw-Hill Book Company, New York, NY.

Taggart, Arthur F.

1945 Handbook of Mineral Dressing: Ores and Industrial Minerals. John Wiley & Sons, Inc., New York City, NY.

United States Bureau of Mines

1942 Elizabeth Mine, Orange County, VT. War Minerals Report 2 - Copper (November), United States Department of the Interior, United States Bureau of Mines, Washington, DC.

1943 Elizabeth Mine, Orange County, VT, Supplement to War Minerals Report 2. War Minerals Report 135 - Copper (November), United States Department of the Interior, United States Bureau of Mines, Washington, DC.

Wark, Ian W.

1938 Principles of Flotation. Australasian Institute of Mining and Metallurgy, Melbourne, Australia.

E. Likely Sources Not Yet Investigated

(None identified)

LIST OF FIGURES

1. Location Map showing Vermont, Orange County, and Elizabeth Mine site vicinity (Ford et al. 2003:2).

2. Detail showing approximate boundaries of Elizabeth Mine Site on USGS South Strafford 7.5 minute quadrangle, 1981, USGS, Reston, VA.

3. Enlarged area of Elizabeth Mine Site showing major landforms on USGS South Strafford 7.5 minute quadrangle, 1981, USGS, Reston, VA.

4. Location map showing Orange County Copper Belt mines (Kierstead 2000:3/15).

5.

5. Generalized geological map of the Vermont Copper Belt (Seal et al. 2000:117, Figure 1).

6. Historic Photograph of 1898 Adit at official opening of Elizabeth Mine, 1943 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

7. "Plot of Buildings and Facilities at Elizabeth Mine and Copper Concentrate Processing Plant Now in Operation at South Strafford," from "Vermont Copper Company's Big Mining Enterprise Now Well Established at South Strafford, VT." Randolph, VT, Herald 14 Dec 1944.

8. Historic photograph of Elizabeth Mine plant looking west, ca. 1950 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

9. Historic photograph of Elizabeth Mine plant looking northwest from Tailings Pile 2, 1962 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

10. Historic photograph of Elizabeth Mine plant looking southwest from Tailings Pile 1, 1962 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

11. Historic photograph of Elizabeth Mine plant looking west from Tailings Pile 1, with Concentrating Mill, Thickener/Filter Building, and Heating Plant at center, 1962 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

12. Historic photograph of mine car tramline looking north, after 1948 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

13. Historic photograph of electric mine car locomotive with driver, ca. 1950 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

14. Historic photograph of North Open Cut looking north about 1949 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

15. Historic photograph of cable shovel in South Open Cut, ca. 1950-1953 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

16. Historic photograph of Elizabeth Mine plant and Tailings Pile looking northeast after 1952 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

17. Historic photograph of Elizabeth Mine plant looking northeast across Tailings Pile 1, showing tailings pipelines, after 1948 (Calvert Smith photographs, Elizabeth Mine Study Group, Strafford, VT).

18. Plan of area of core 1942-1958 operations, showing footprint of World War II-era mine plant buildings, roads, and Tailings Piles 1 and 2.

19. Detail map of core World War II-era mine plant buildings.

20. Aerial photograph taken April 29, 2000, of Elizabeth Mine plant, with Tailings Pile 1 at right edge and Tailings Pile 2 at lower right (Aerodata Digital Mapping, Ossipee, NH).

21. Contour map of South Open Cut.

22. Contour map of Copperas Works Area and North Open Cut.

23. Contour map of Tailings Pile 1 and Tailings Pile 2.

24. "Vermont Copper Company Elizabeth Mine Vertical Section Along Strike of Vein, August 1942" (USBM 1942, Figure 3).

25. "Vertical Longitudinal Projection of Ore Zone, Elizabeth Mine, Vermont Copper Company, Inc., Orange County, Vermont," (USBM 1943, Figure 1).

26. "Vertical Longitudinal Projection of Ore Zone, Elizabeth Mine, Vermont Copper Company, Inc., Orange County, Vermont," (Jacobs 1944, Figure 1).

27. Detail from "Longitudinal Section, Vermont Copper Co., Inc. Elizabeth Mine, South Strafford, VT, August 23, 1949 (Vermont Copper Company, Inc., Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

28. Detail from "Elizabeth Mine, Vermont Copper Co., Inc. Elizabeth Mine, South Strafford, VT, August 23, 1949, Plan," (Vermont Copper Company, Inc., Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

29. 975 ft Station Layout (Benson et al. 1950:21).

30. "Vertical Longitudinal Projection of Ore Zone, Elizabeth Mine, Vermont Copper Company, Inc., South Strafford, Vermont, February 1950." (Benson et al. 1950:20).

31. "Longitudinal Section Looking West, Showing Workings." (McKinstry and Mikkola 1954:4).

32. Longitudinal section drawing of mining progress, 1957 (Kierstead 2000) (This map is a composite created by Arthur D. Little, Inc. as a report

supplement. It is accurate north of the 1948 Shaft, where it was based on company records. It does not show the ultimate extent of mining south of the 1948 Shaft, which is shown in Howard 1969).

33. Longitudinal section drawing of mining progress as of 1958 (Howard 1969, Figure 2).

34. Schematic profile drawing of Elizabeth Mine sublevel stoping method (Benson et al. 1950:21).

35. Schematic section of typical shrinkage stoping method (Peele 1941:10/275, Figure 430).

36. Mill Flowsheet, ca. 1944-1948 (Jacobs 1944:9).

37. Technical illustration of Blake-type jaw crusher (Richards and Locke 1925:9, Figure 5a and 5b).

38. Technical illustration of vibrating screen (Taggart 1945:7/48, Figure 39).

39. Technical illustration of cone crusher (Hoffman 1913:540, Figure 330).

40. Technical illustration of Marcy ball mill (Richards and Locke 1925:71, Figure 51).

41. Technical illustration of spiral classifier (Taggart 1945:8/14, Figure 4).

42. Technical illustration, cross-section of Agitair patent flotation cell (Taggart 1945:12/71, Figure 40).

43. Historic photograph of coarse tailings being deposited on tailings pile dam. Photograph by Richard H. Little. The Elizabeth Miner, Strafford Historical Society, Strafford, VT.

44. Schematic section of typical tailings disposal pile showing launder trestle, coarse sand dams and fine slime backfilling (Taggart 1945:20/37, Figure 27).

45. Technical illustration of Dorr rotary rake thickener (Taggart 1945:15/14, Figure 13).

46. Technical illustration of Oliver continuous filter (Taggart 1945:16/04, Figure 4).

47. Mill Flowsheet, ca. 1948-1952 (Benson et al. 1950:22).

48. Technical illustration of American disc filter (Taggart 1945:16/11, Figure 9).

49. Mill Flowsheet, ca. 1952-1958 (Jutjen and Kearney 1953:74).

Figure 1.Location Map showing Vermont, Orange County, and Elizabeth Mine Site

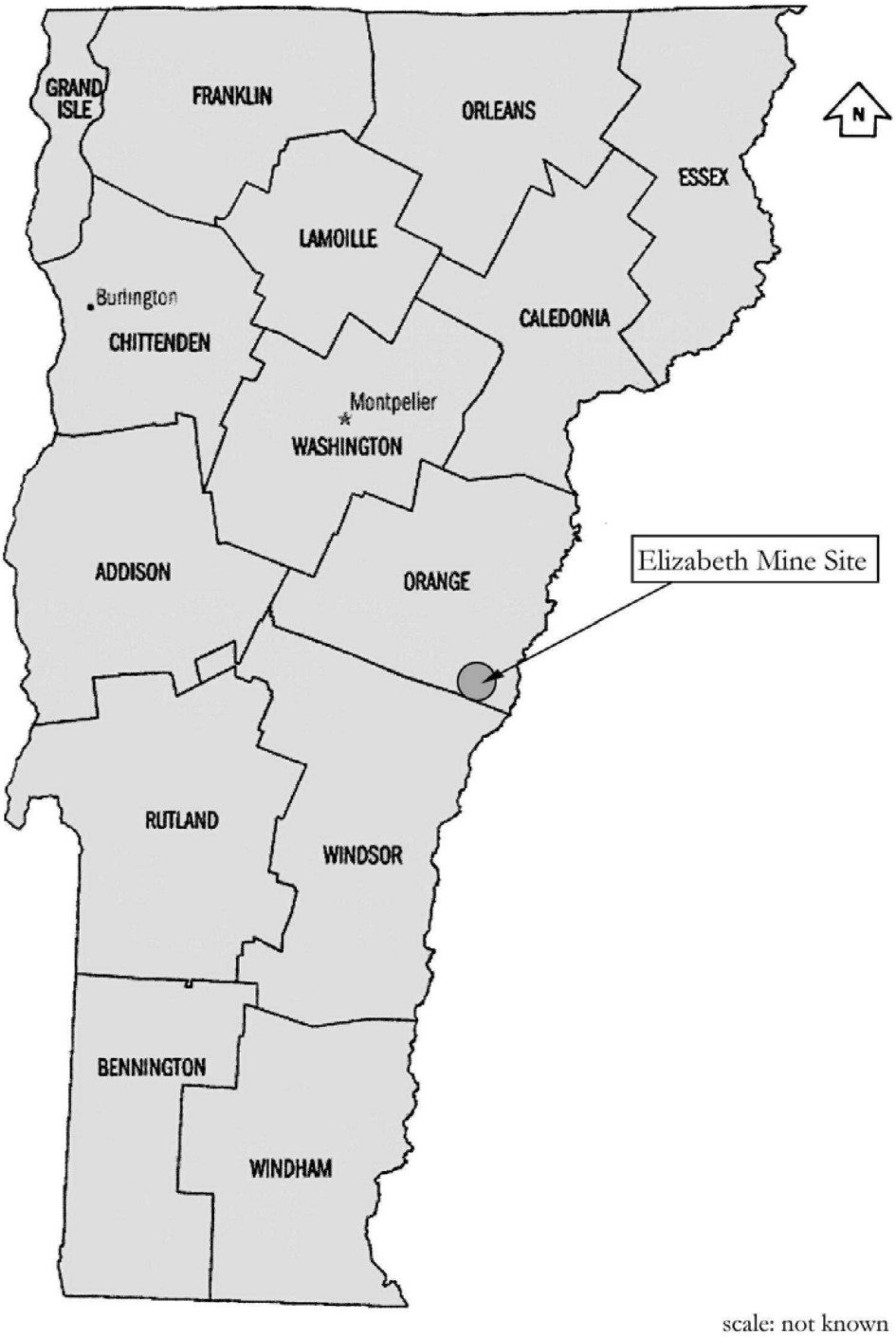


Figure 2. Detail map showing approximate boundaries of Elizabeth Mine Site

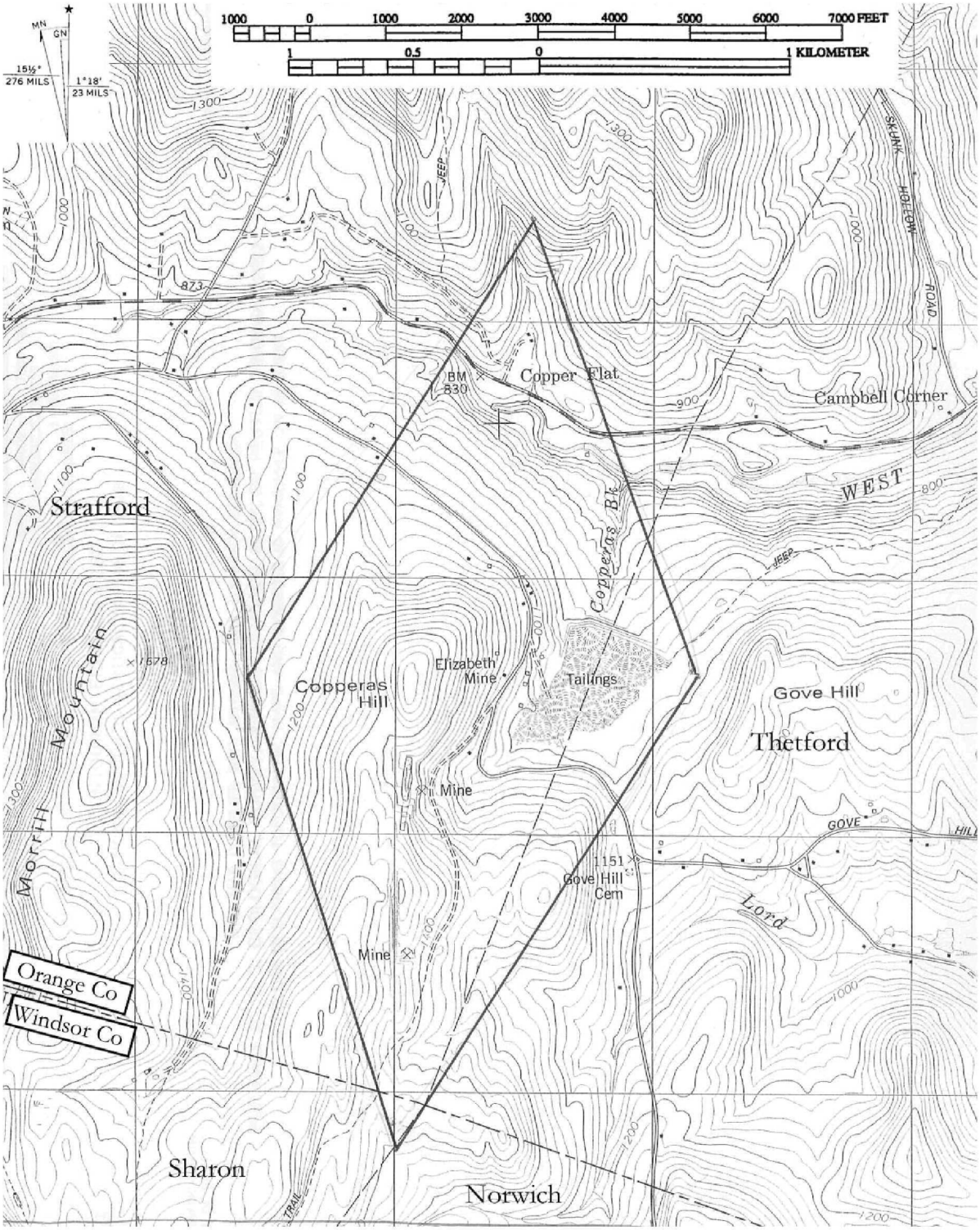


Figure 3. Enlarged area of Elizabeth Mine Site showing major landforms

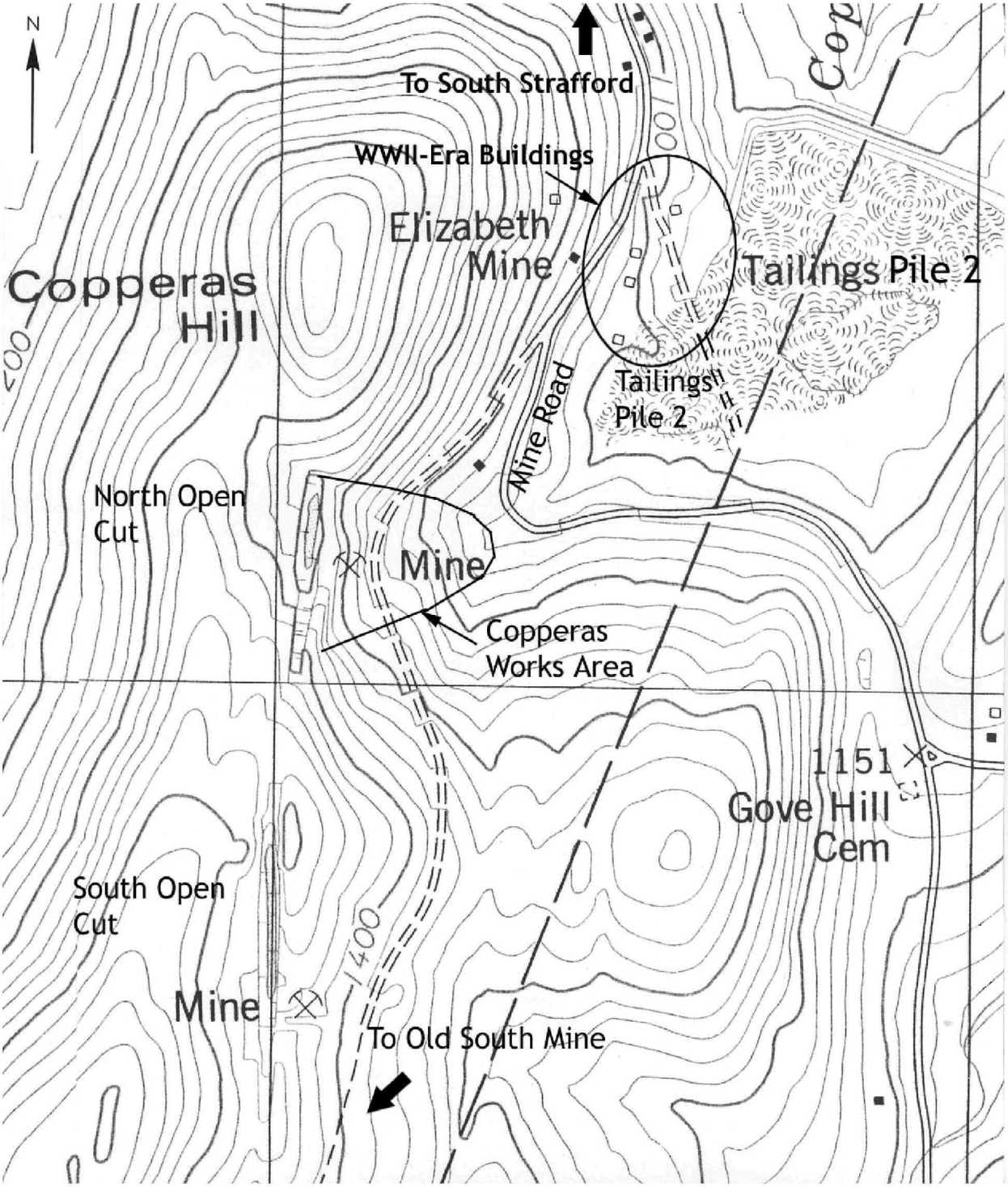


Figure 4. Location map showing Orange County Copper Belt mines

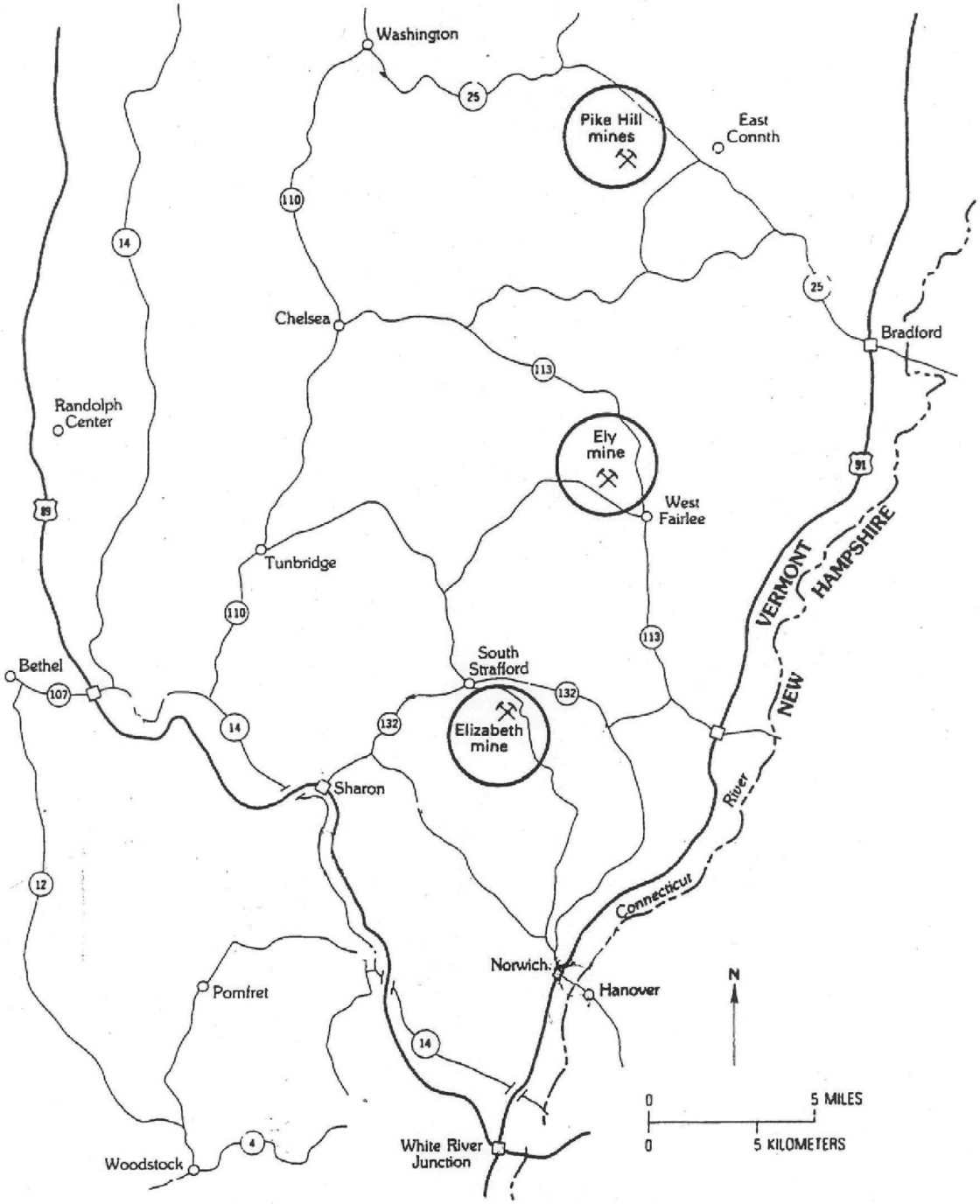


Figure 5. Generalized geological map of the Vermont Copper Belt

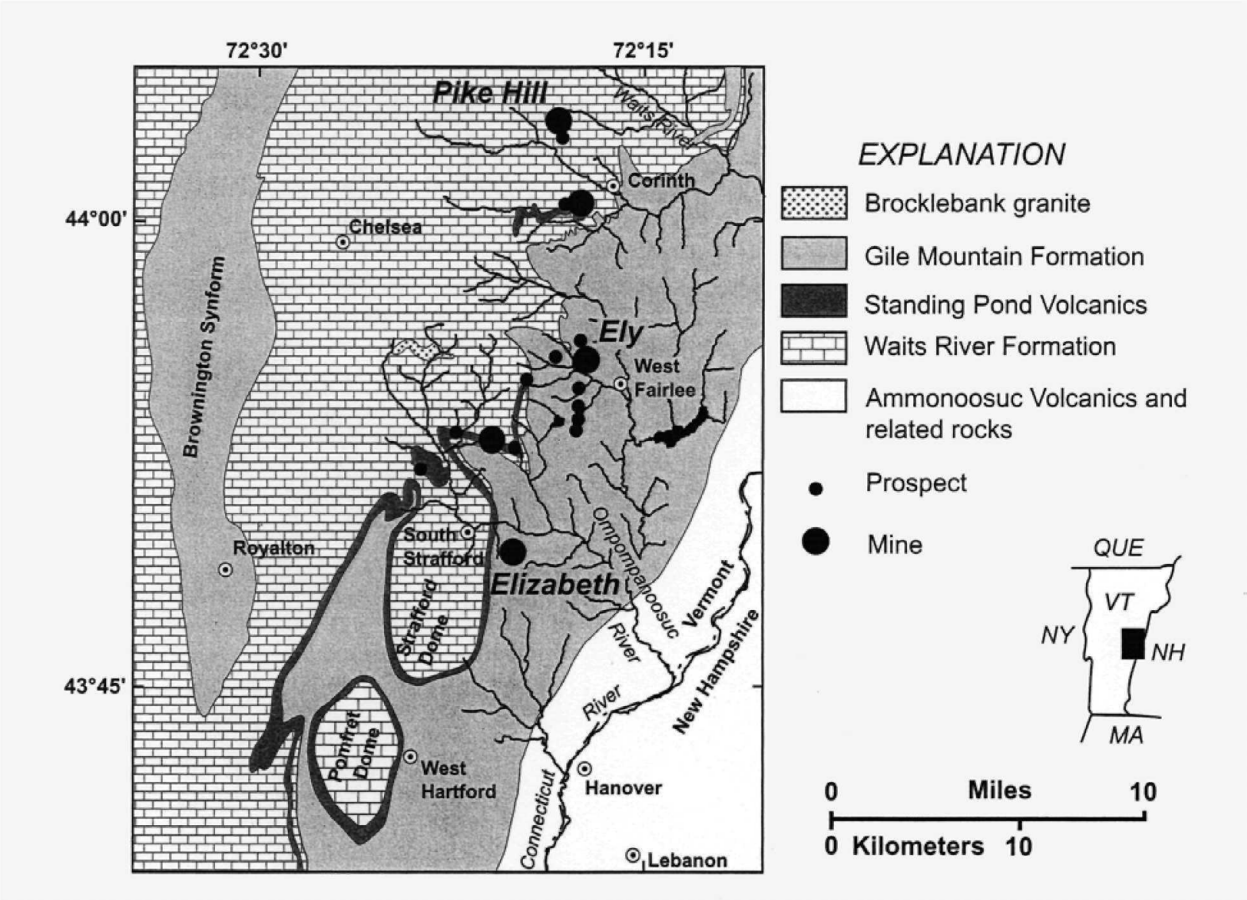


Figure 6. Historic Photograph of 1898 Adit at official 1943 opening of Elizabeth Mine

Figure 7. "Plot of Buildings and Facilities at Elizabeth Mine..." December 1944

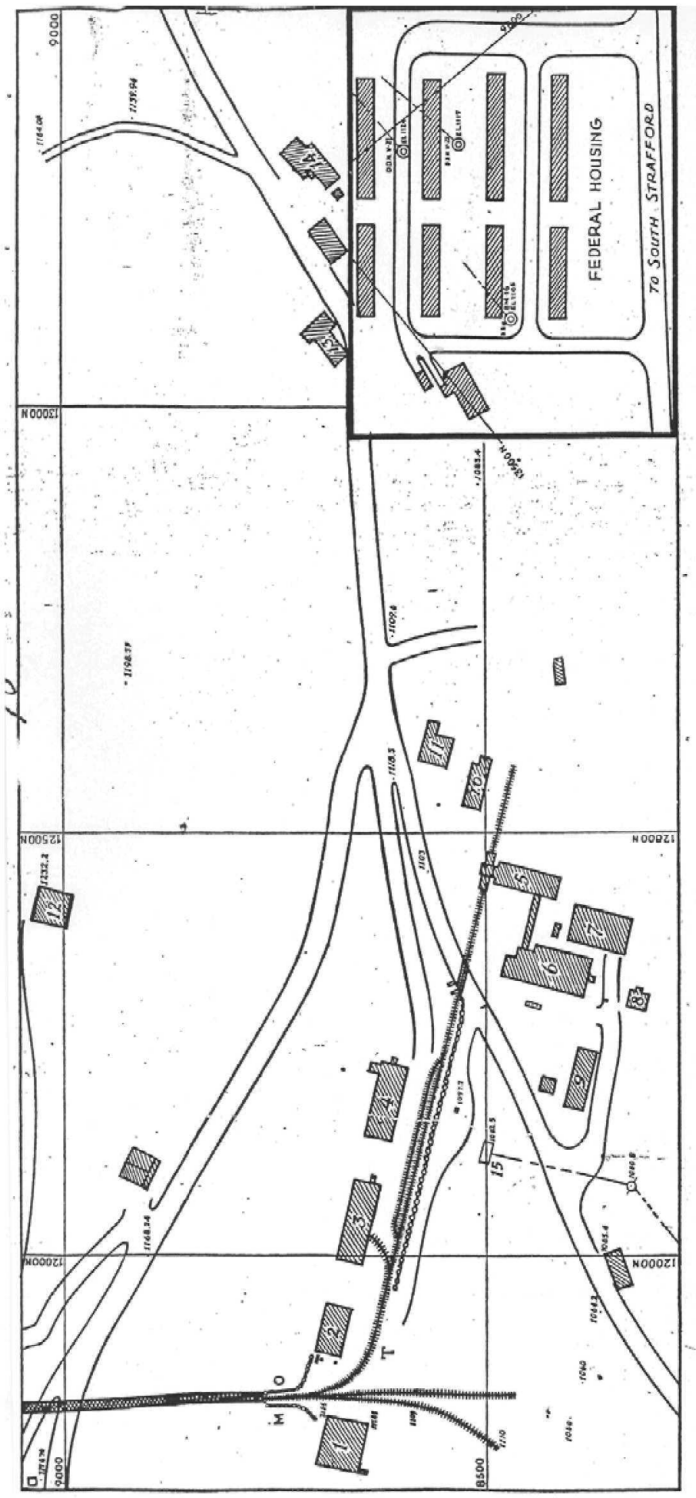


Figure 8. Historic photograph of Elizabeth Mine plant looking west, ca. 1950

Figure 9. Historic photograph of Elizabeth Mine plant looking northwest, 1962

Figure 10. Historic photograph of Elizabeth Mine plant looking southwest, 1962

Figure 11. Historic photograph of Elizabeth Mine plant looking west, 1962

Figure 12. Historic photograph of mine car tram line looking north, after 1948

Figure 13. Historic photograph of electric mine car locomotive with driver, ca. 1950

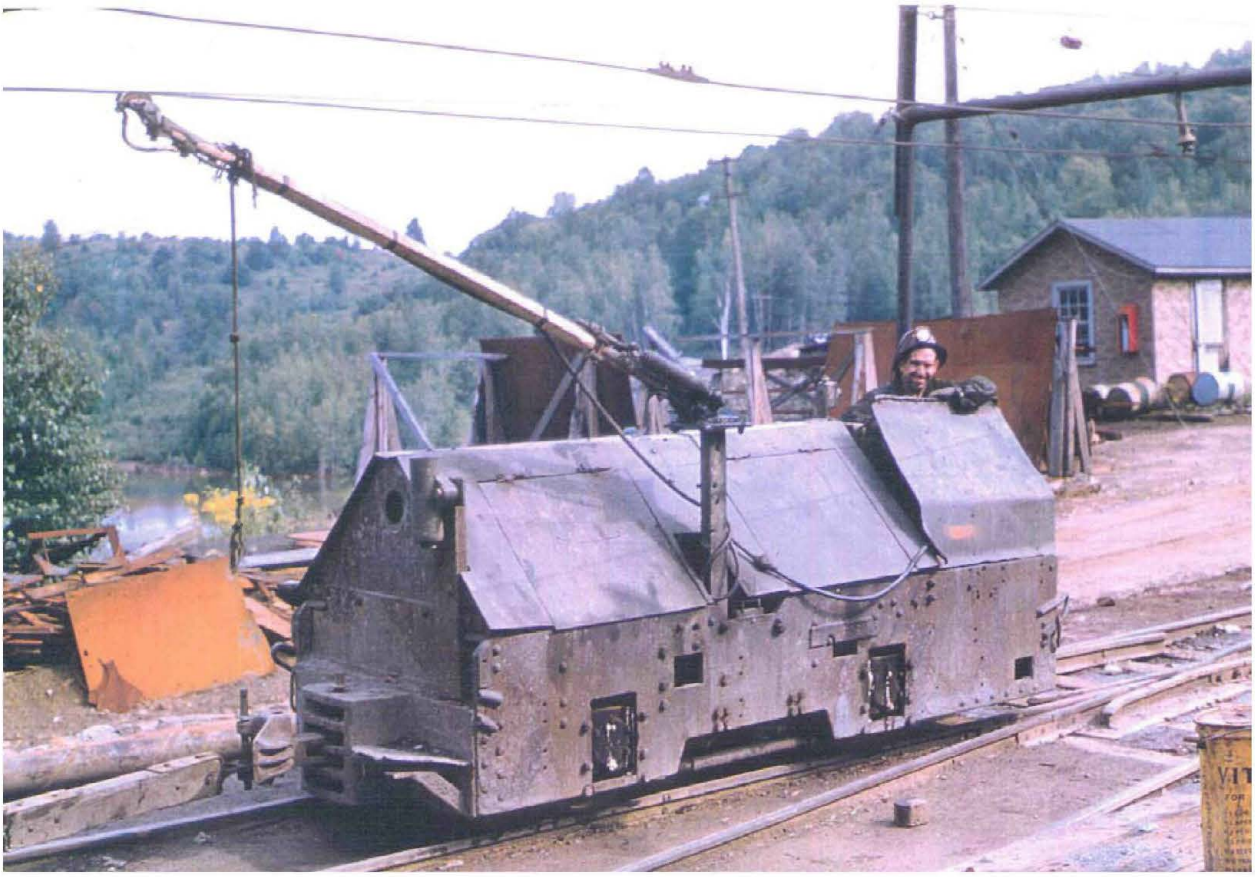


Figure 14. Historic photograph of North Open Cut looking north about 1949

Figure 15. Historic photograph of cable shovel in South Open Cut, ca. 1950-1953

Figure 16. Historic photograph of plant and Tailings Pile 1 looking northeast after 1952

Figure 17. Historic photograph looking northeast across Tailings Pile 1, after 1952

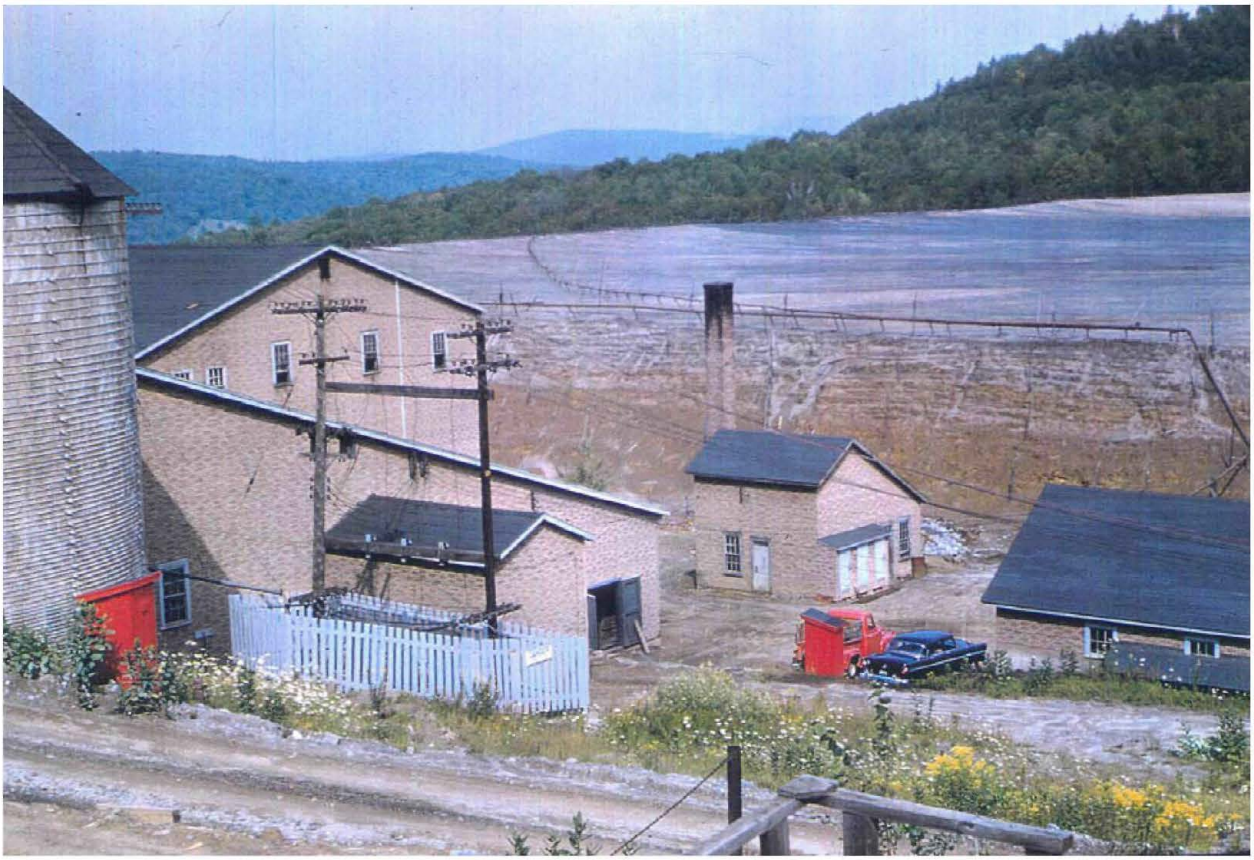


Figure 18. Plan of area of core 1942-1958 operations

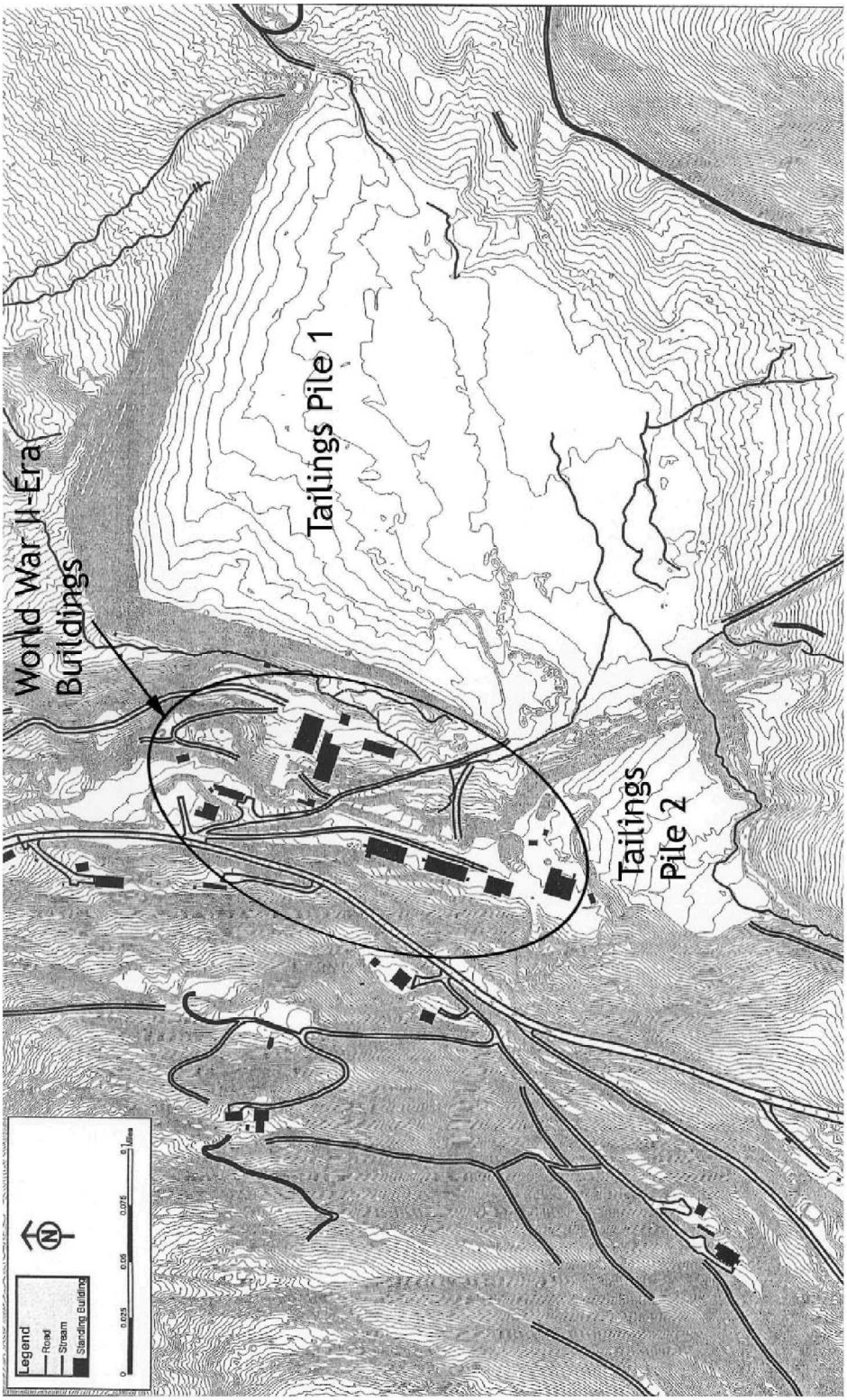


Figure 19. Detail map of core World War II-era mine plant buildings

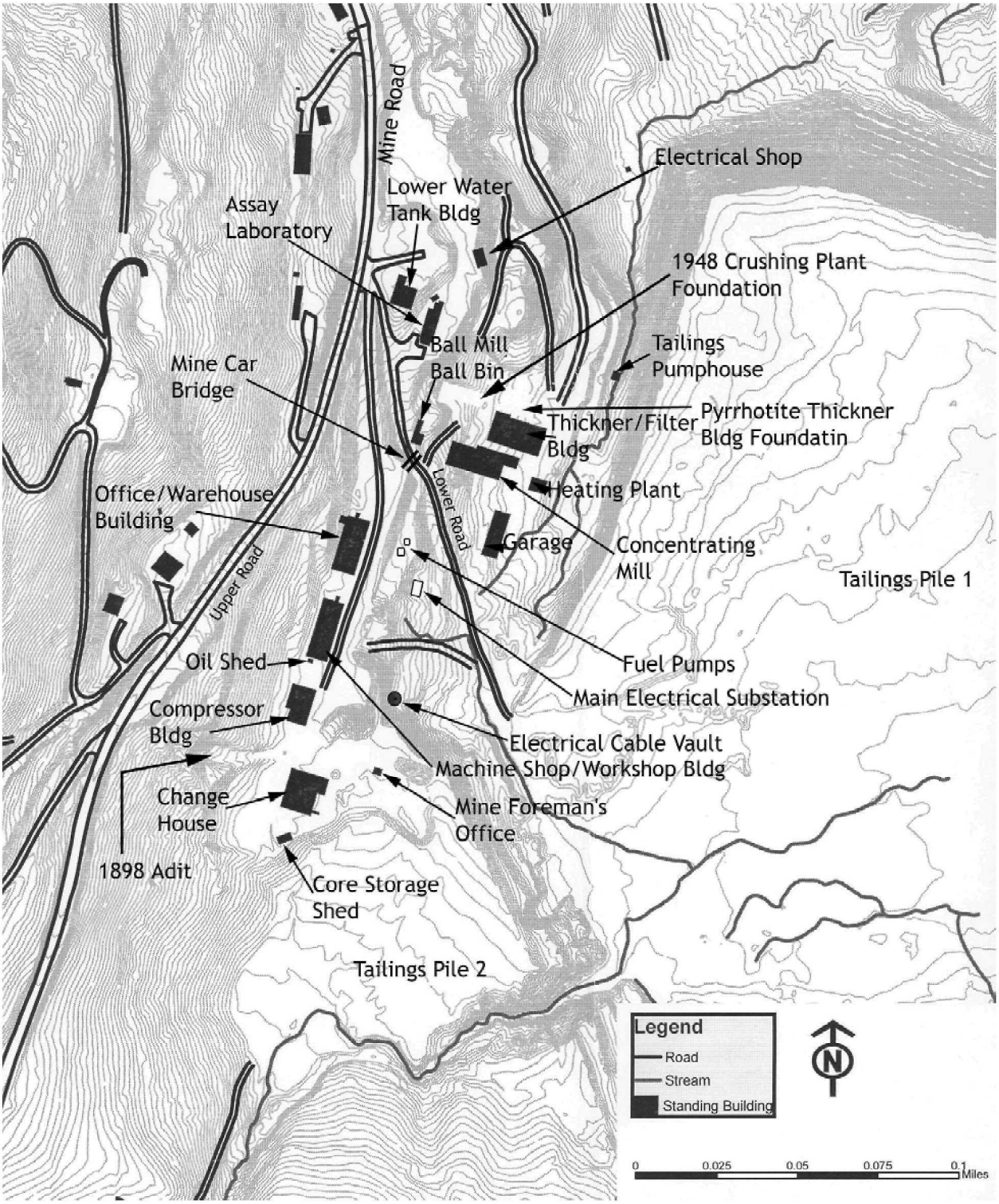


Figure 20. Aerial photograph taken April 29, 2000, of Elizabeth Mine plant

Figure 21. Contour map of South Open Cut

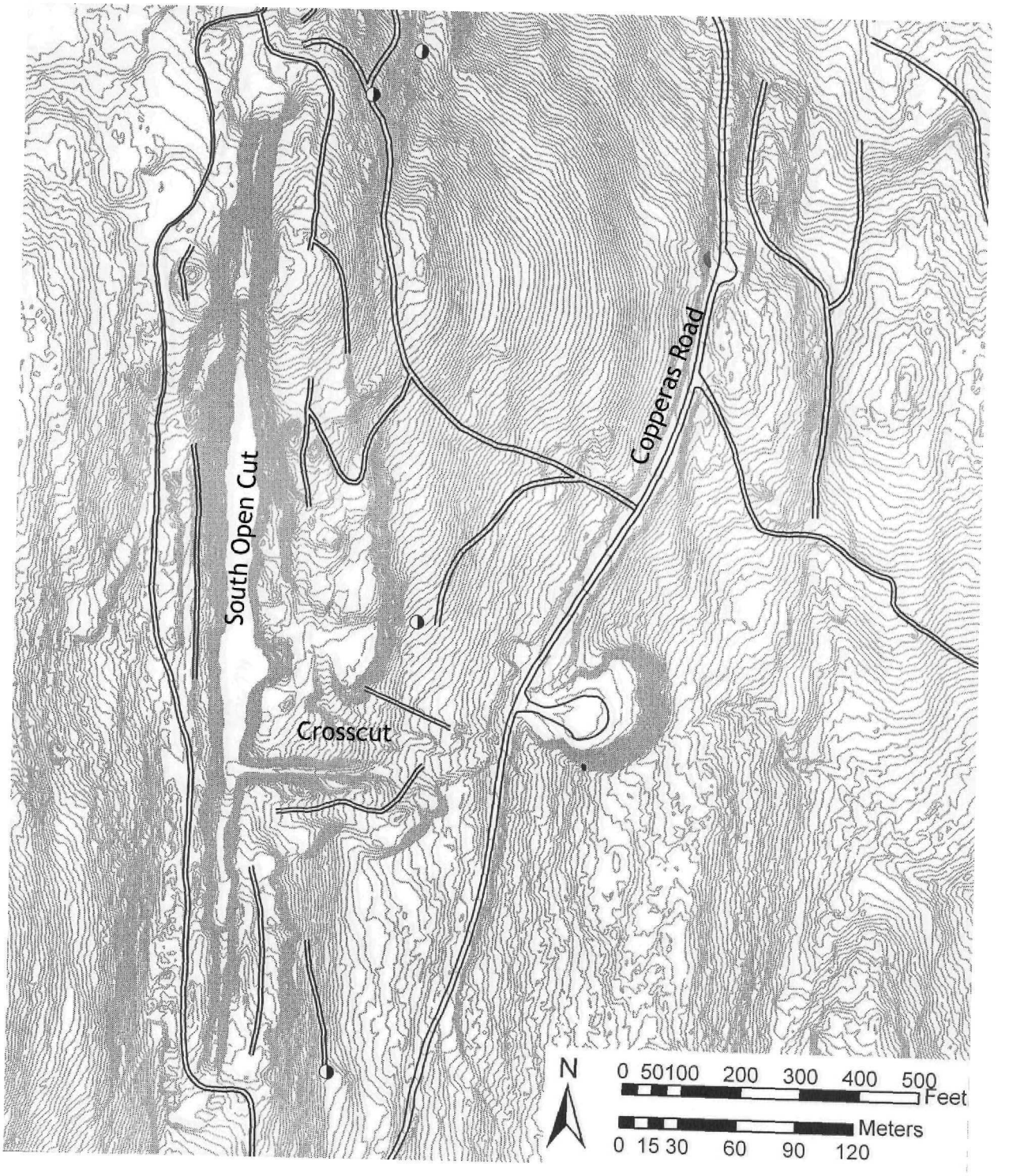


Figure 22. Contour map of Copperas Works Area and North Open Cut

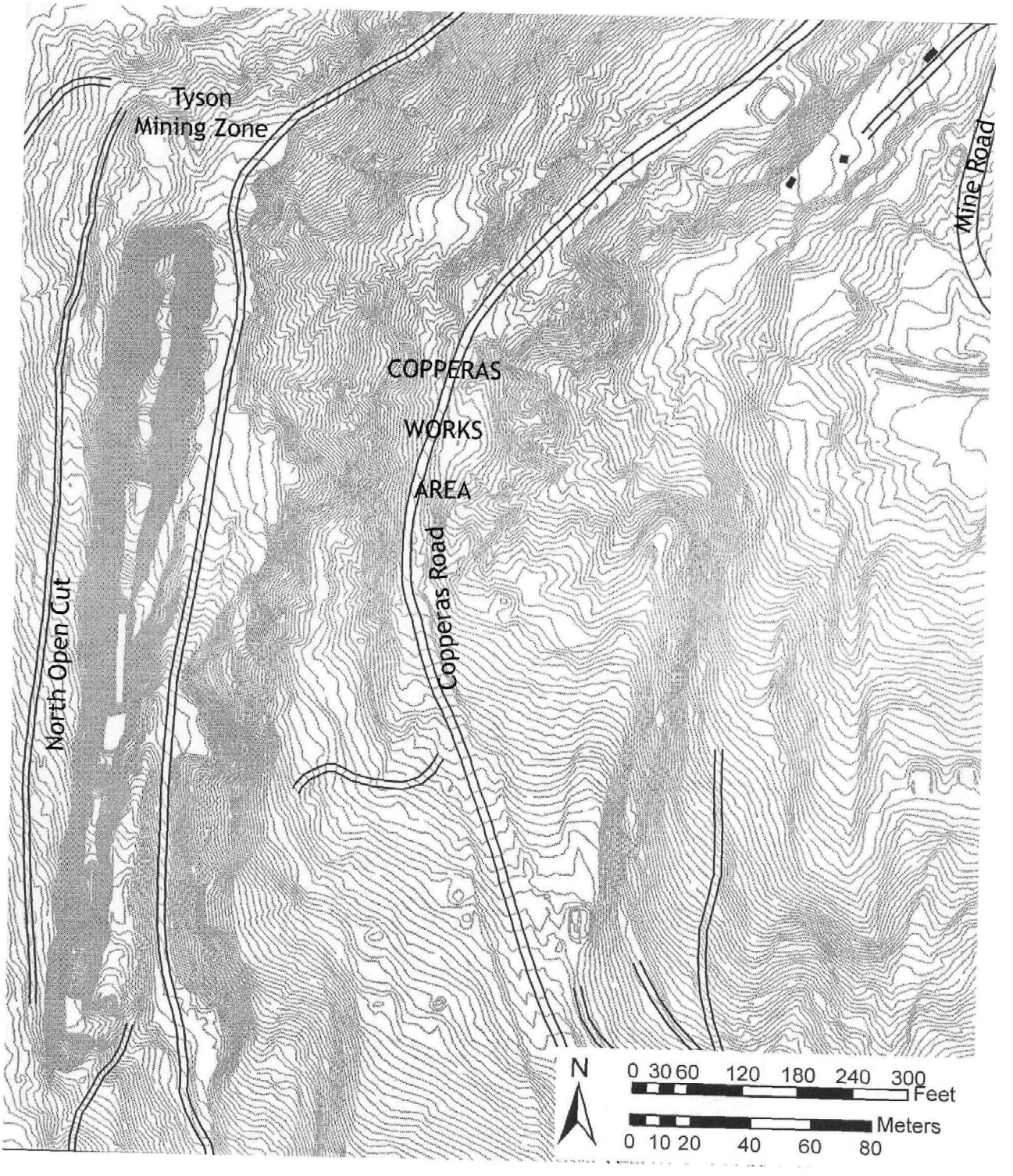


Figure 23. Contour map of Tailings Pile 1 and Tailings Pile 2

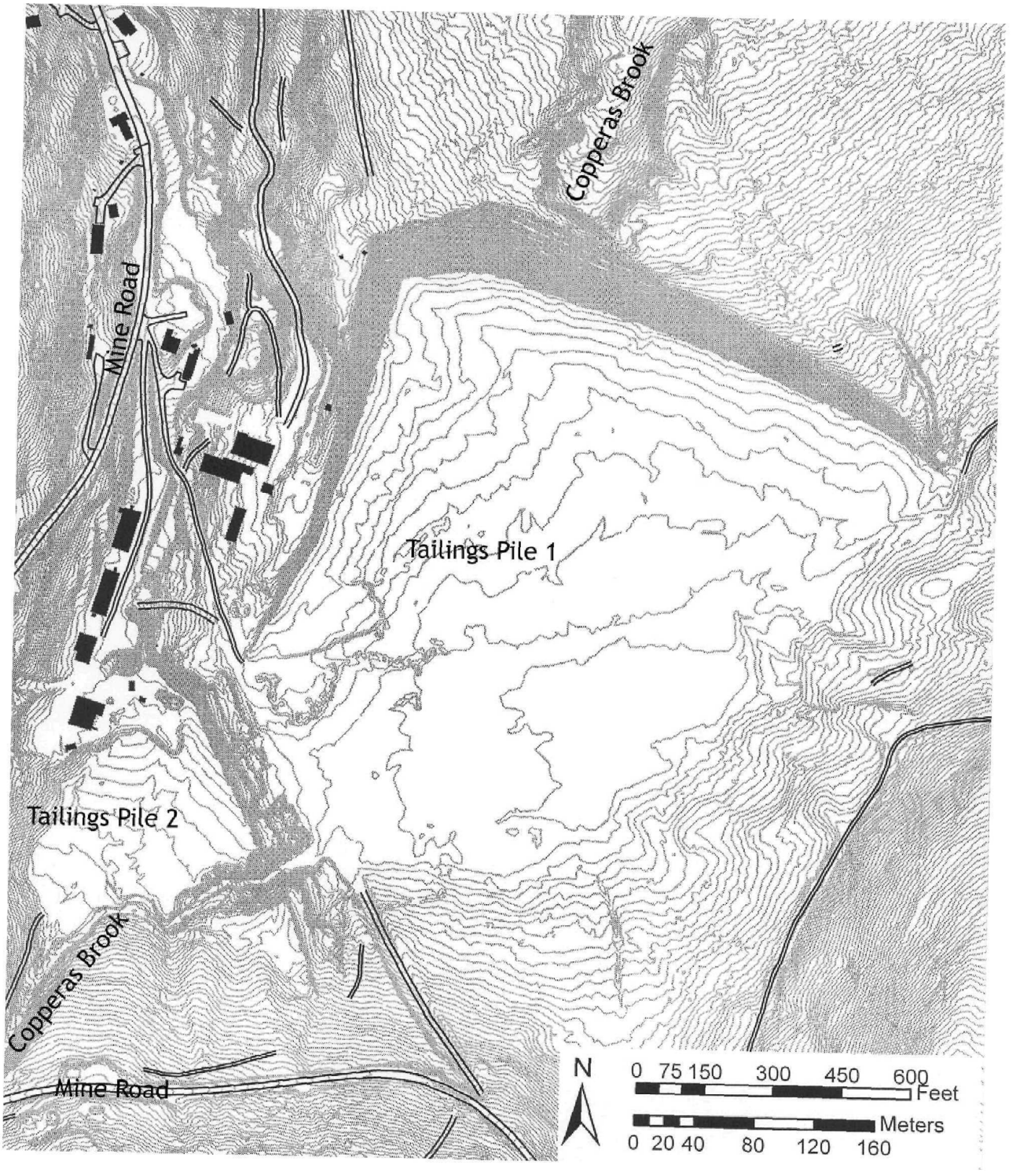


Figure 24. Vertical Section Along Strike of Vein, August, 1942

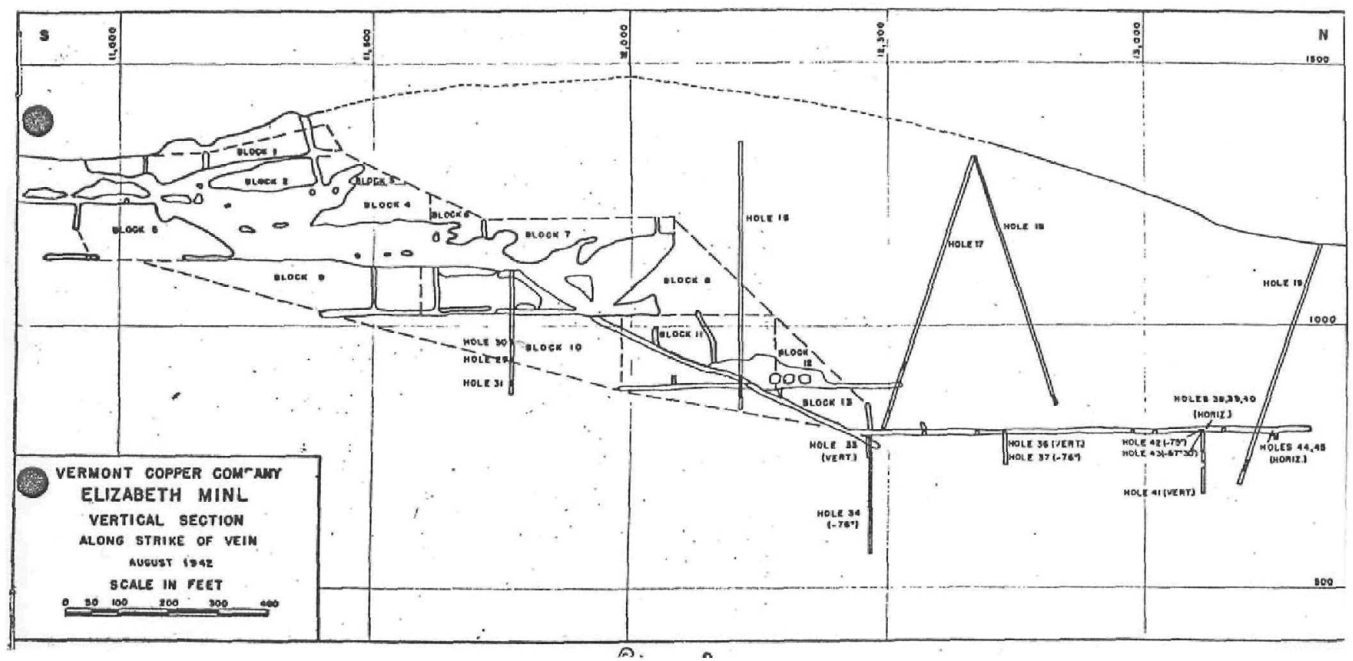


Figure 25. Vertical Longitudinal Projection of Ore Zone, 1943

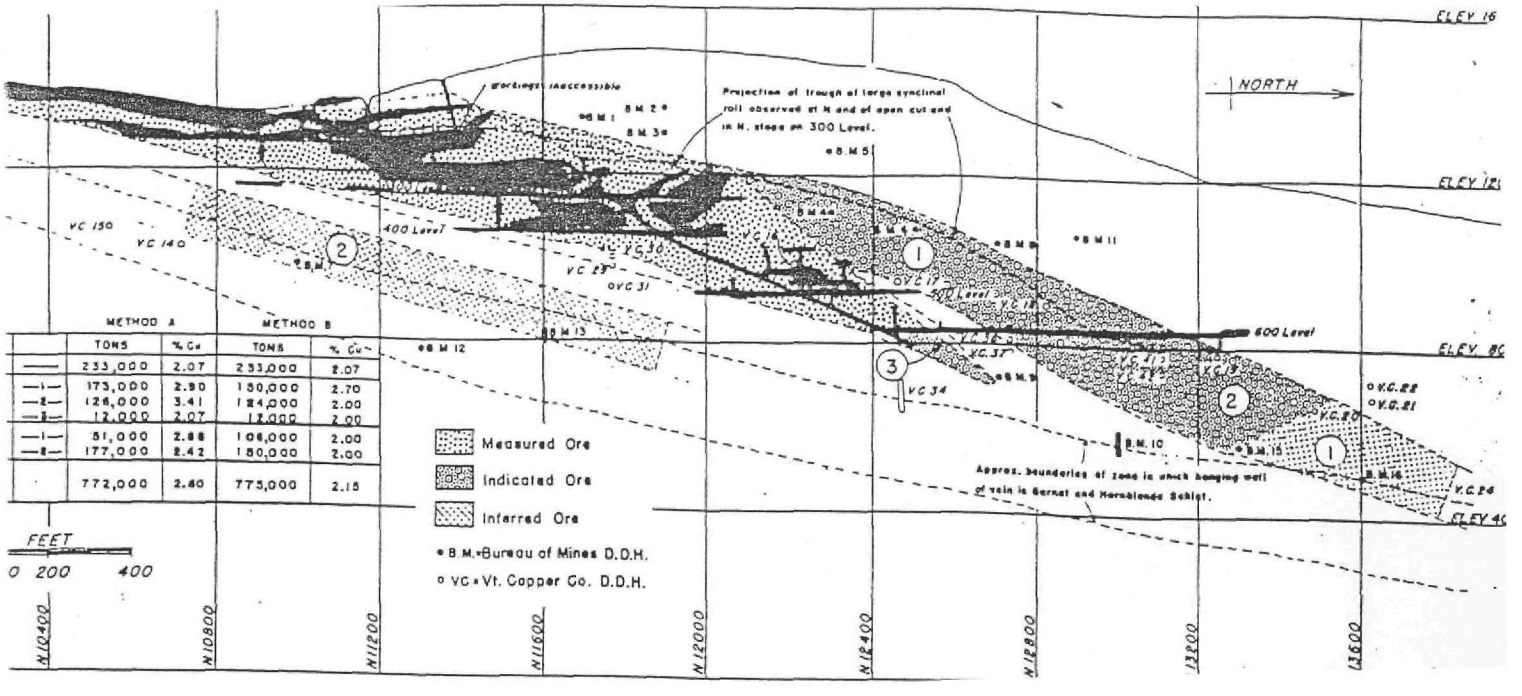


Figure 26. Vertical Longitudinal Projection of Ore Zone, Elizabeth Mine, 1944

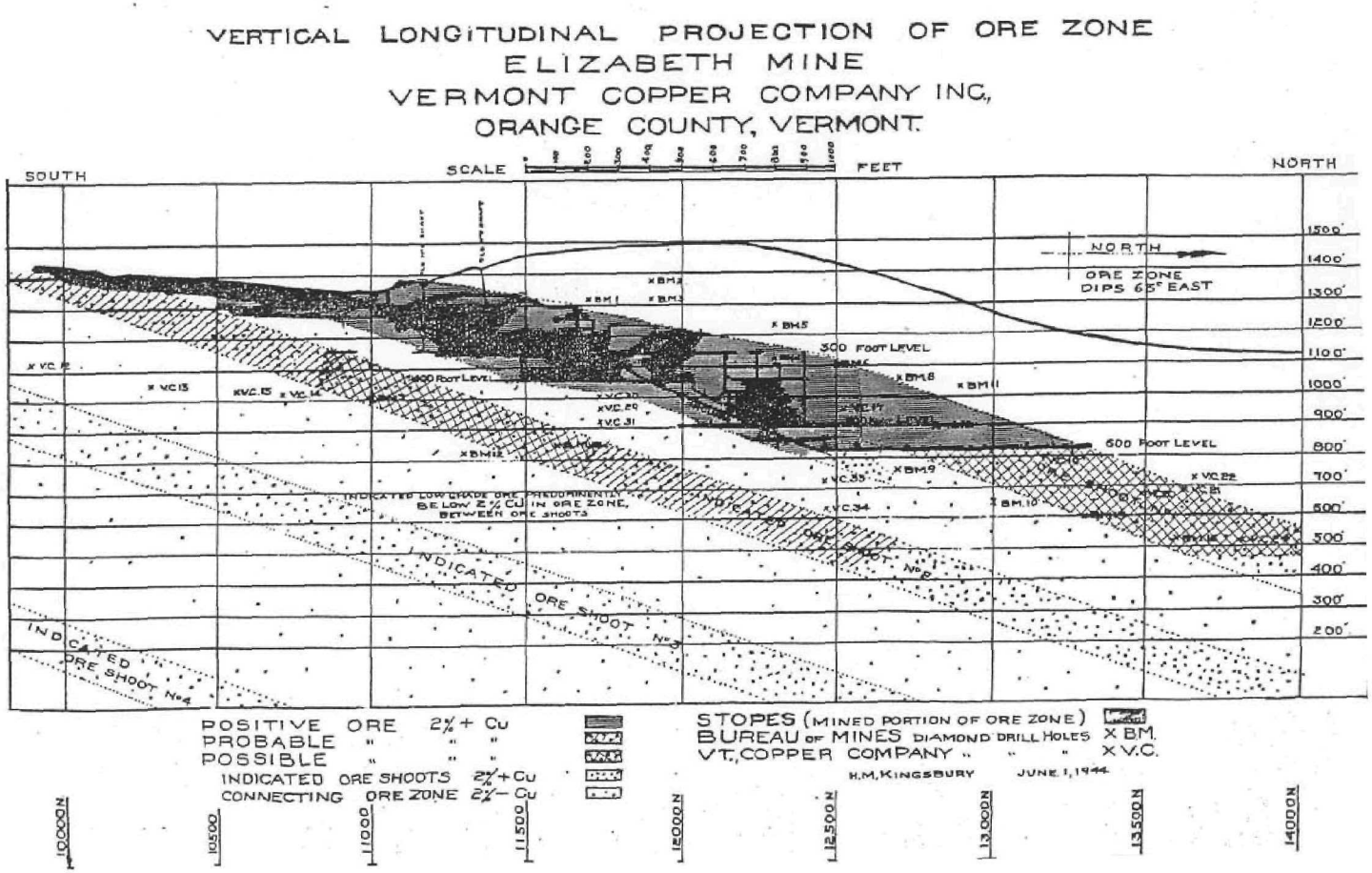


Figure 27. Longitudinal Section of Ore Zone, 1949

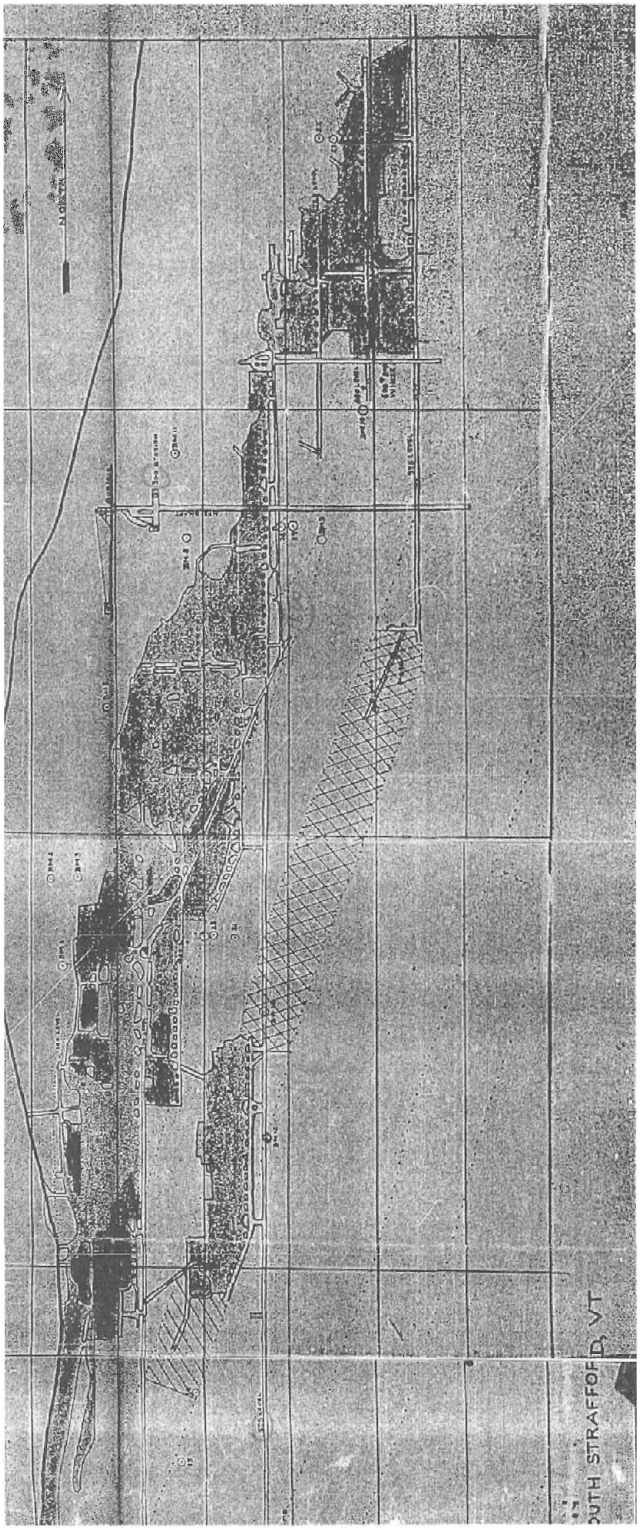


Figure 28. Plan View of Ore Zone, 1949

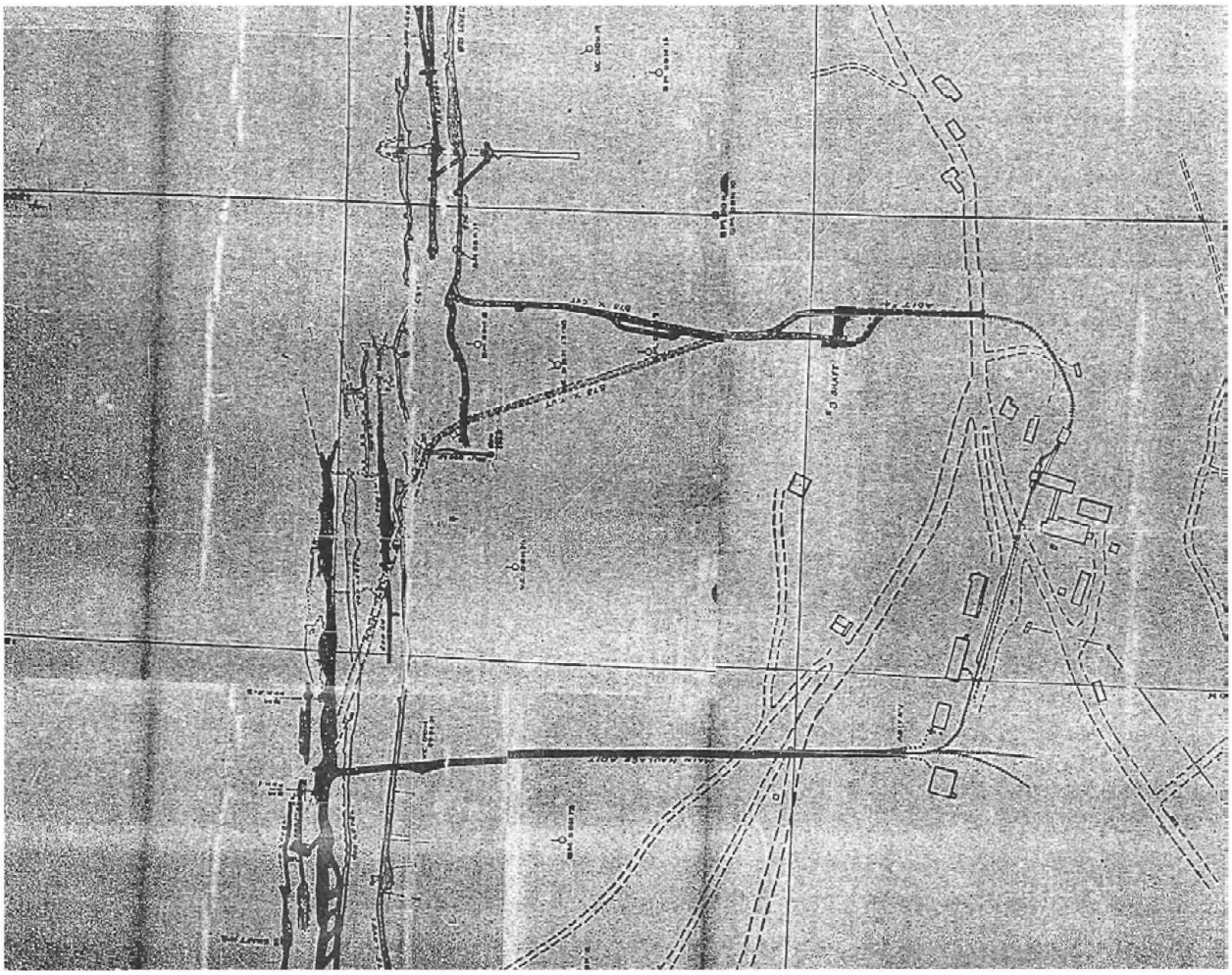
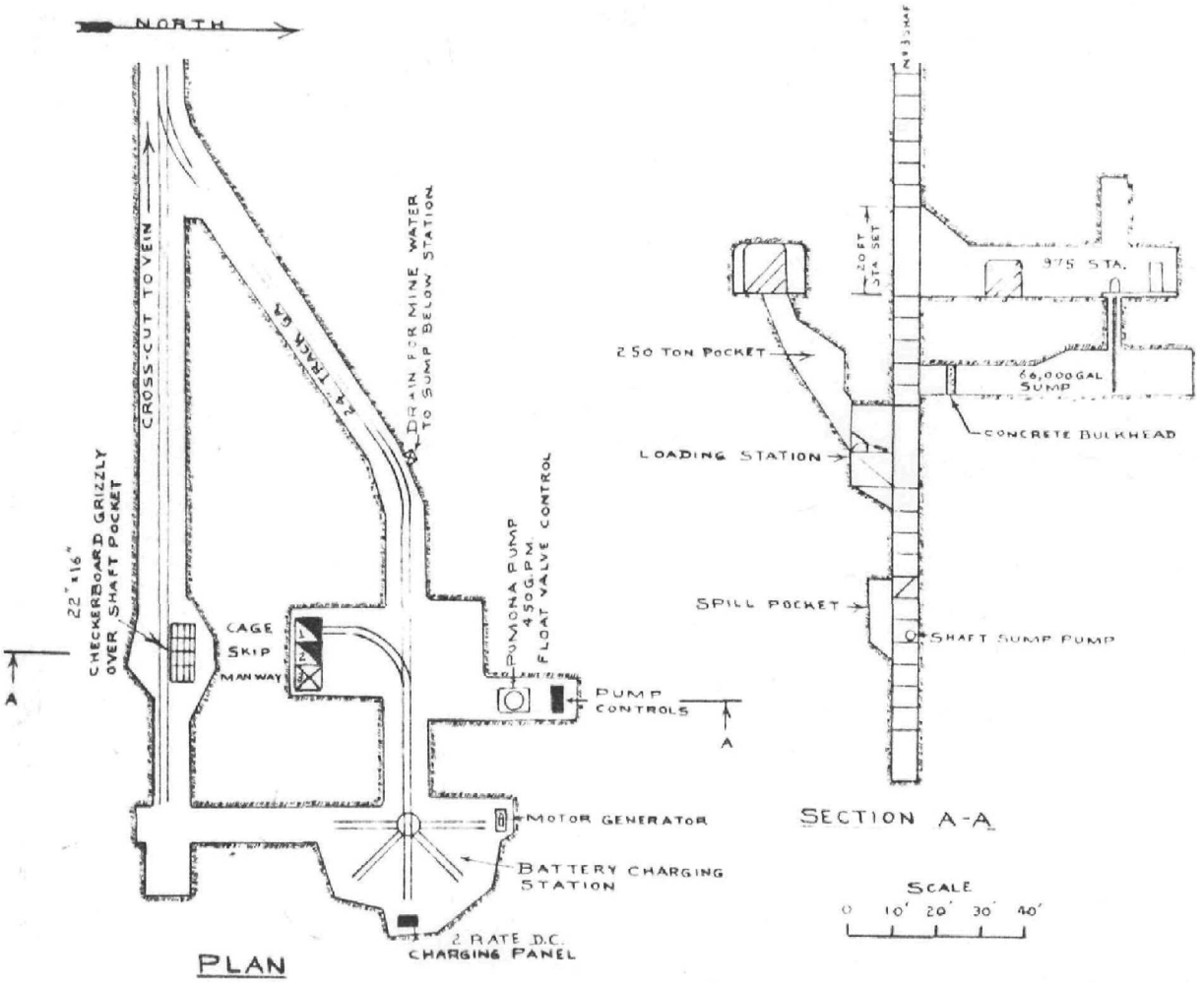


Figure 29. 975 ft Station Layout



975 STATION LAYOUT

Figure 30. Vertical Longitudinal Projection of Ore Zone, February, 1950

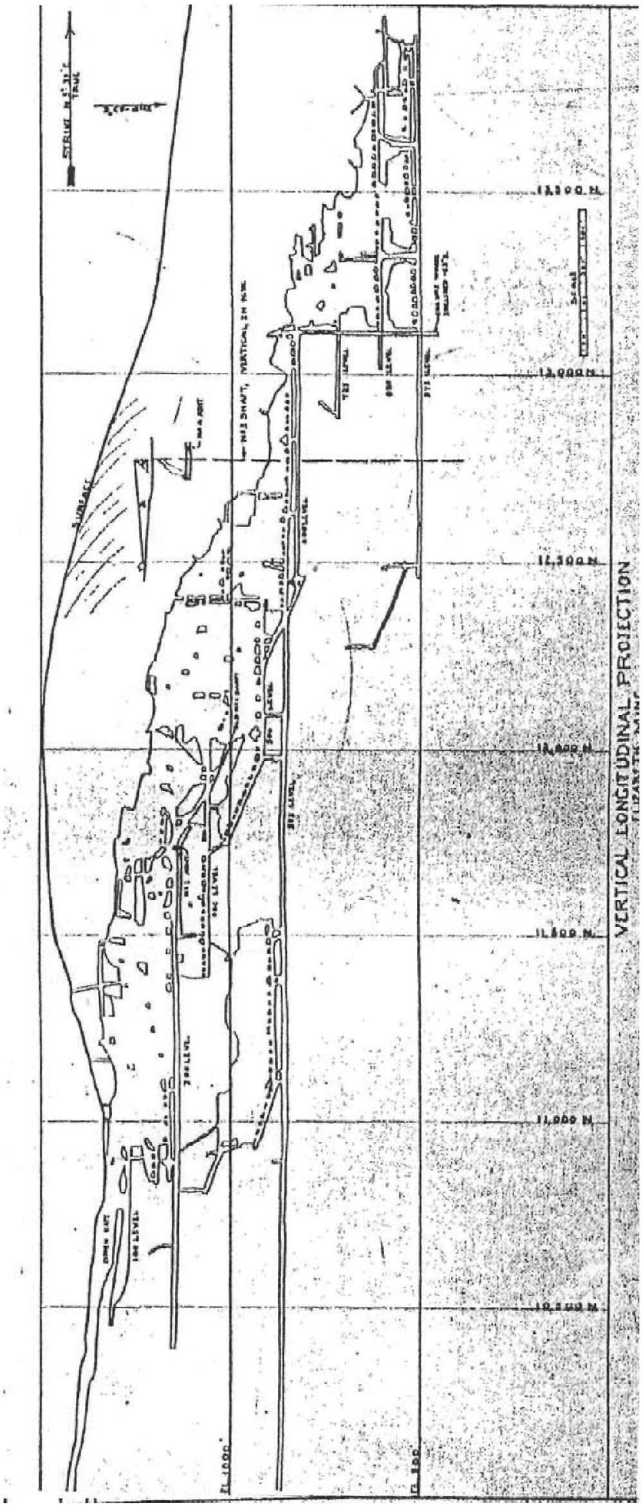
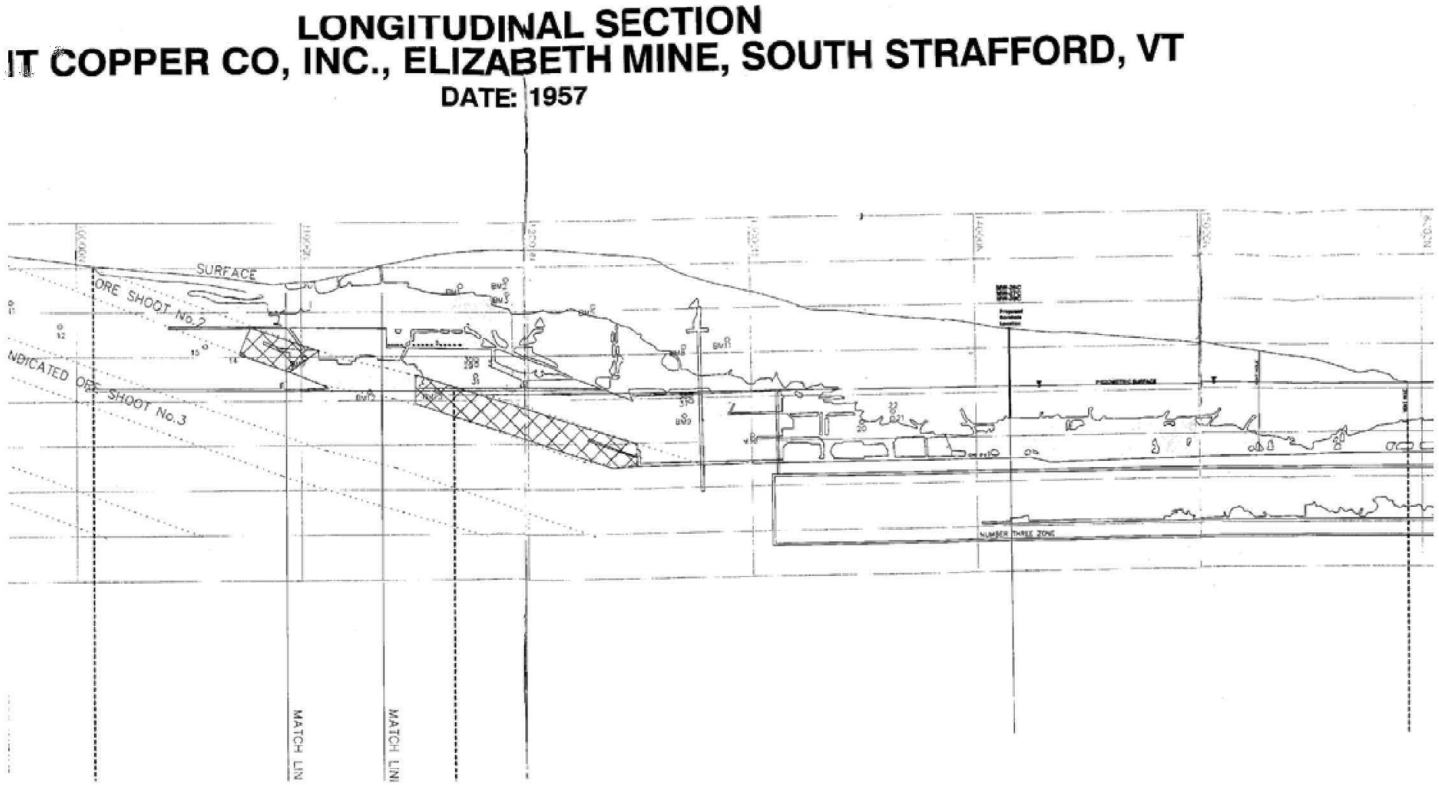
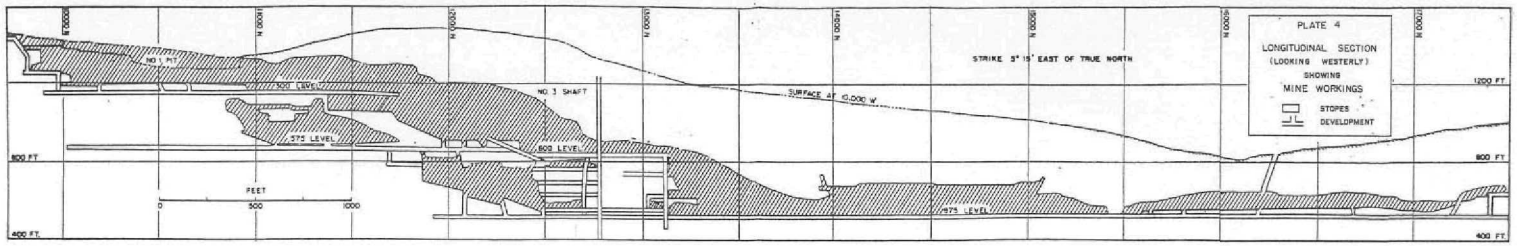


Figure 31. Longitudinal Section Looking West, Showing Workings, 1954

Figure 32. Longitudinal section drawing of mining progress, 1957





ECONOMIC GEOLOGY NO. 5 VERMONT GEOLOGICAL SURVEY

Figure 33. Longitudinal section drawing of mining progress as of 1958

Figure 34. Schematic profile drawing of Elizabeth Mine sublevel stoping method

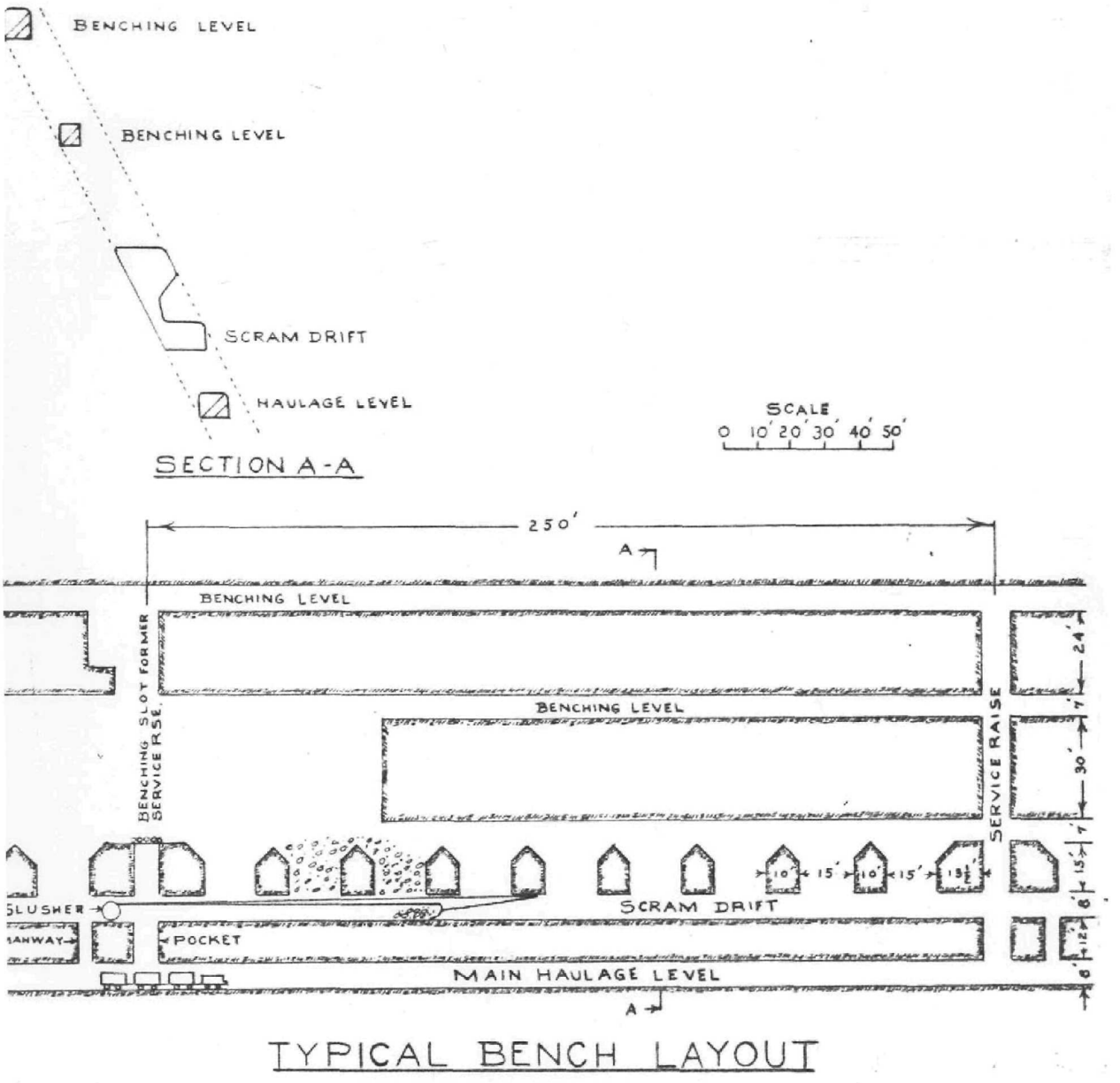


Figure 35. Schematic section of typical shrinkage stoping method

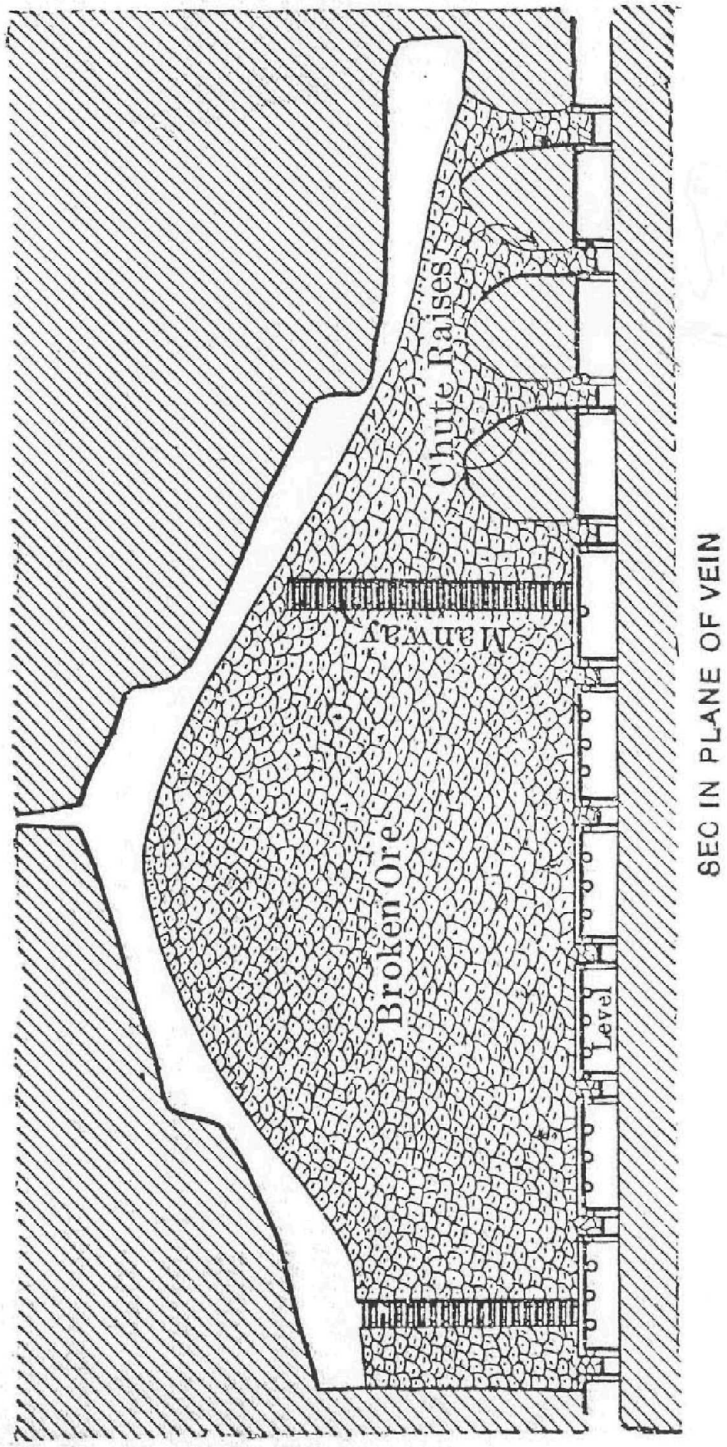


Figure 36. Mill Flowsheet, ca. 1944-1948

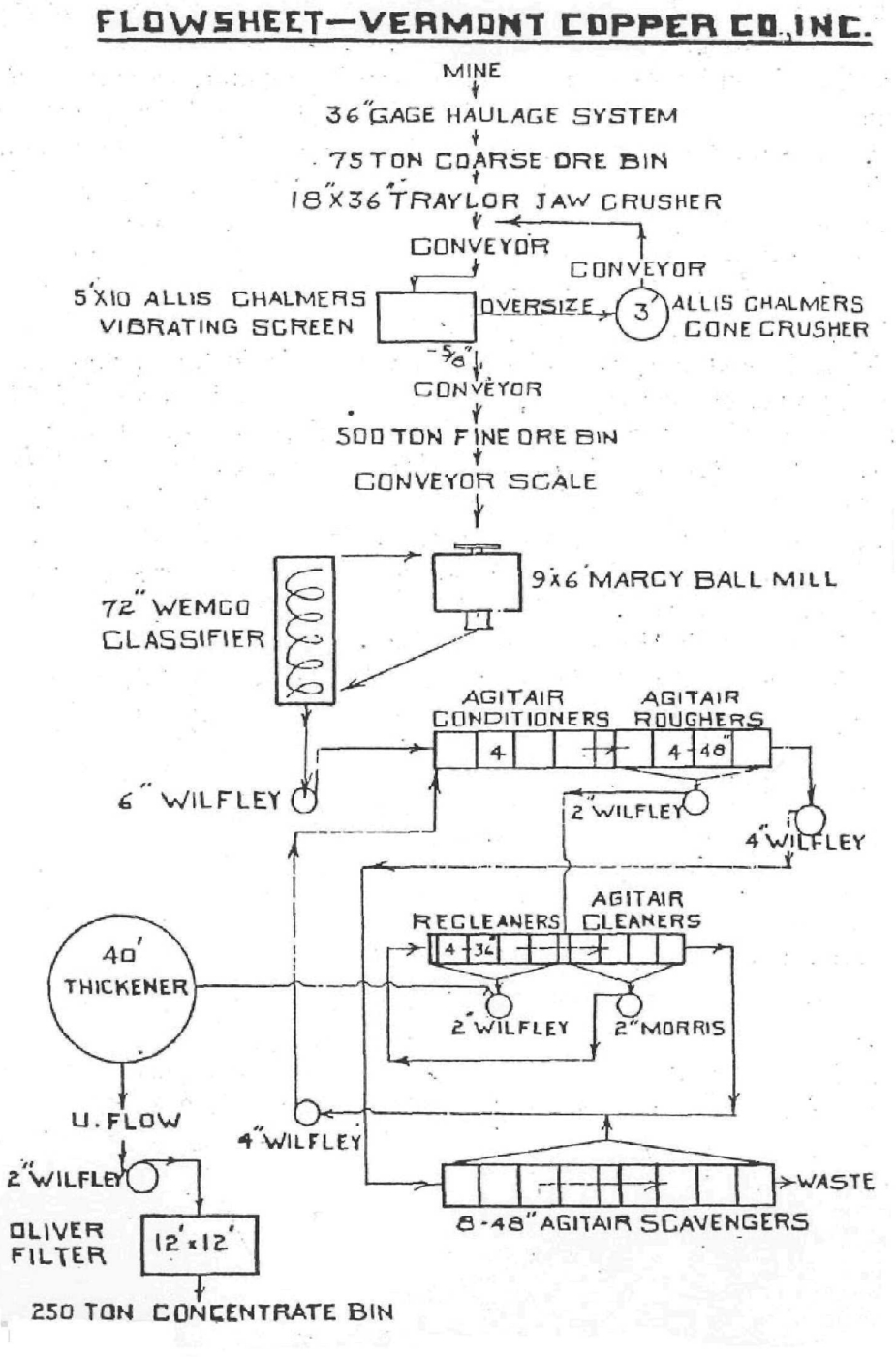


Figure 37. Technical illustration of Blake-type jaw crusher

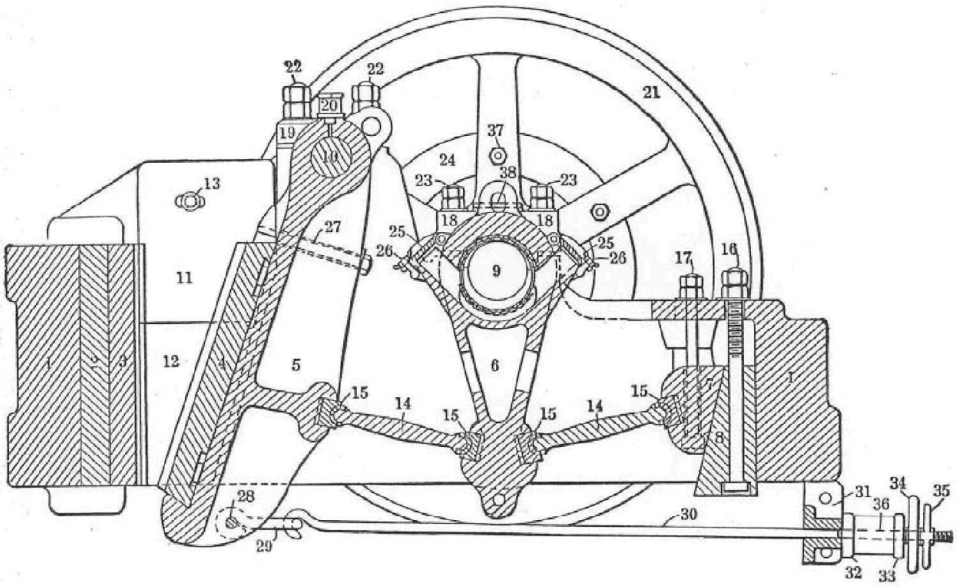


FIG. 5a.—Sectional view of Blake-type breaker.

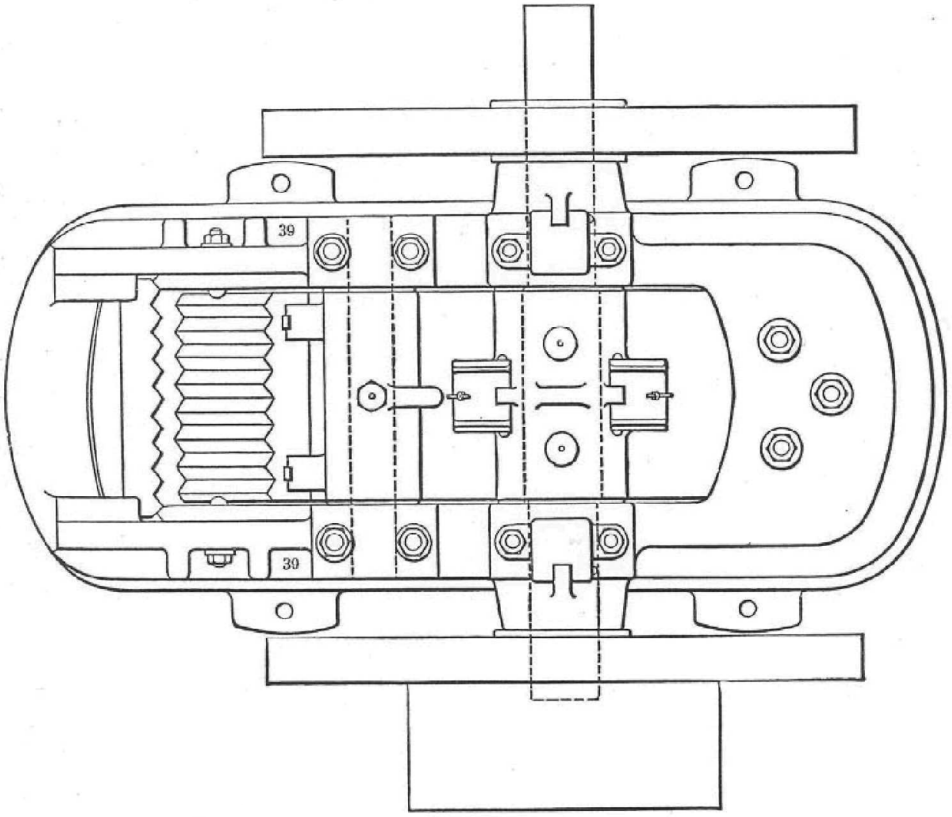


FIG. 5b.—Plan of Blake-type breaker.

Figure 38. Technical illustration of vibrating screen

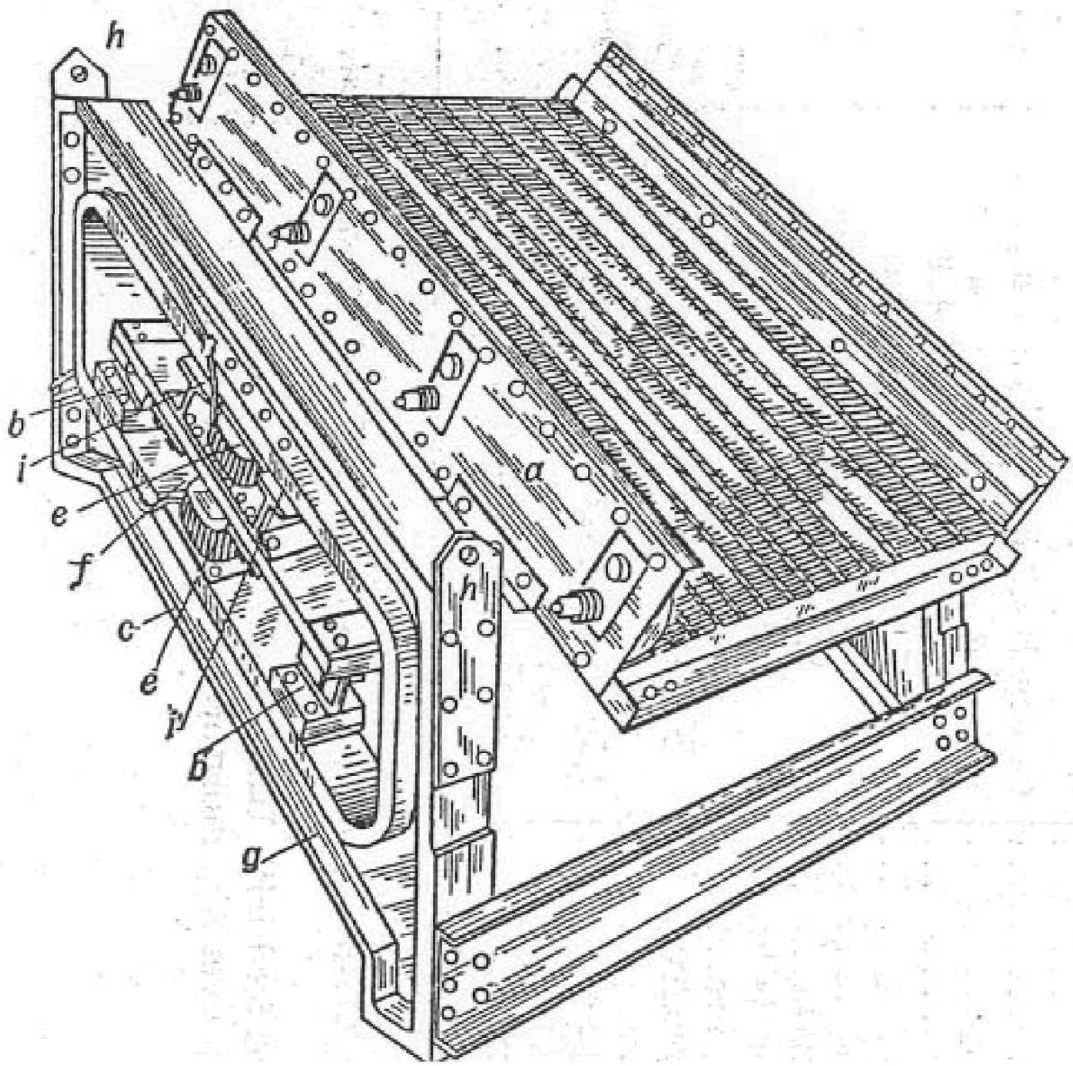


Figure 39. Technical illustration of cone crusher

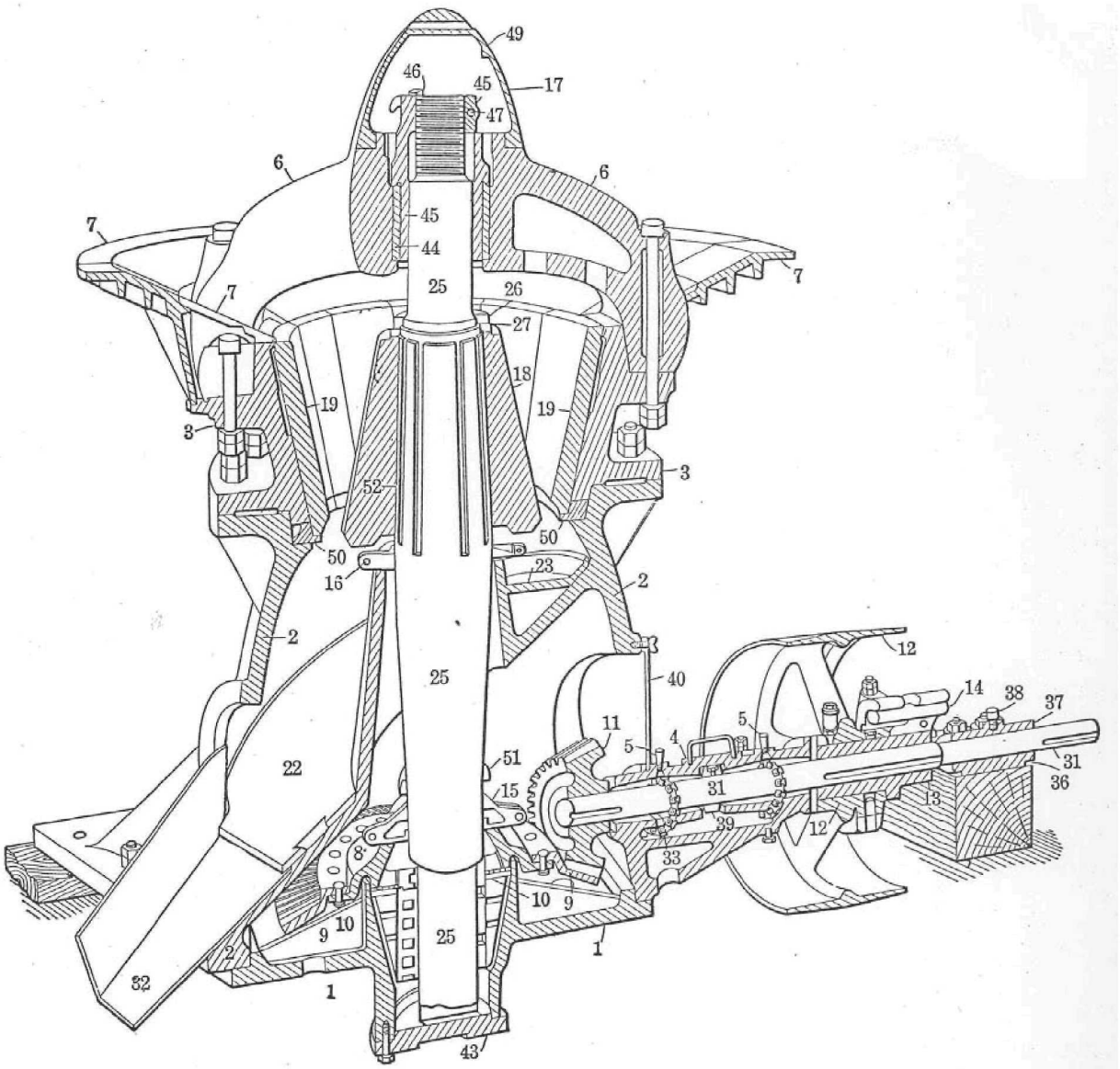


Figure 40. Technical illustration of Marcy ball mill

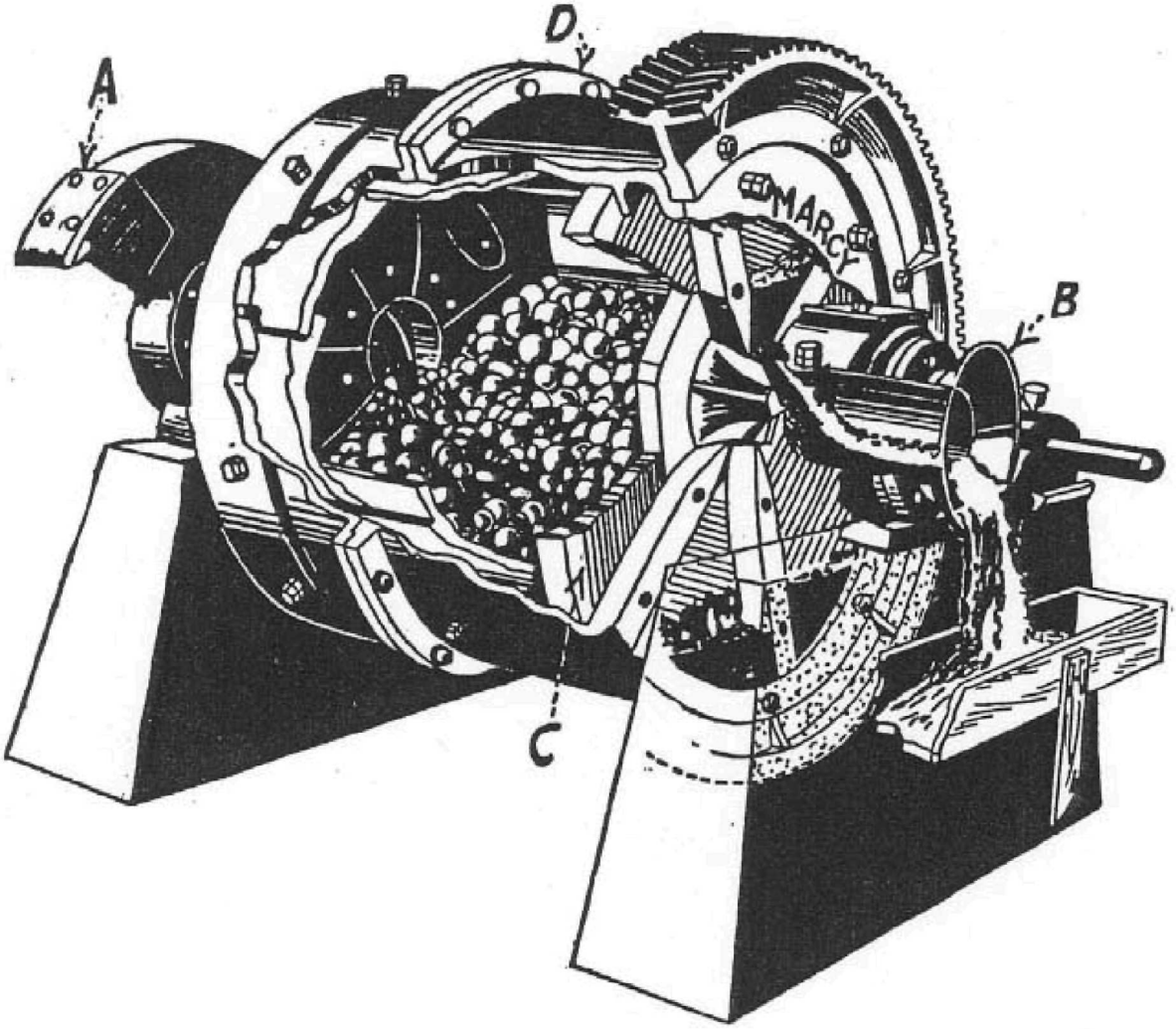


Figure 41. Technical illustration of spiral classifier

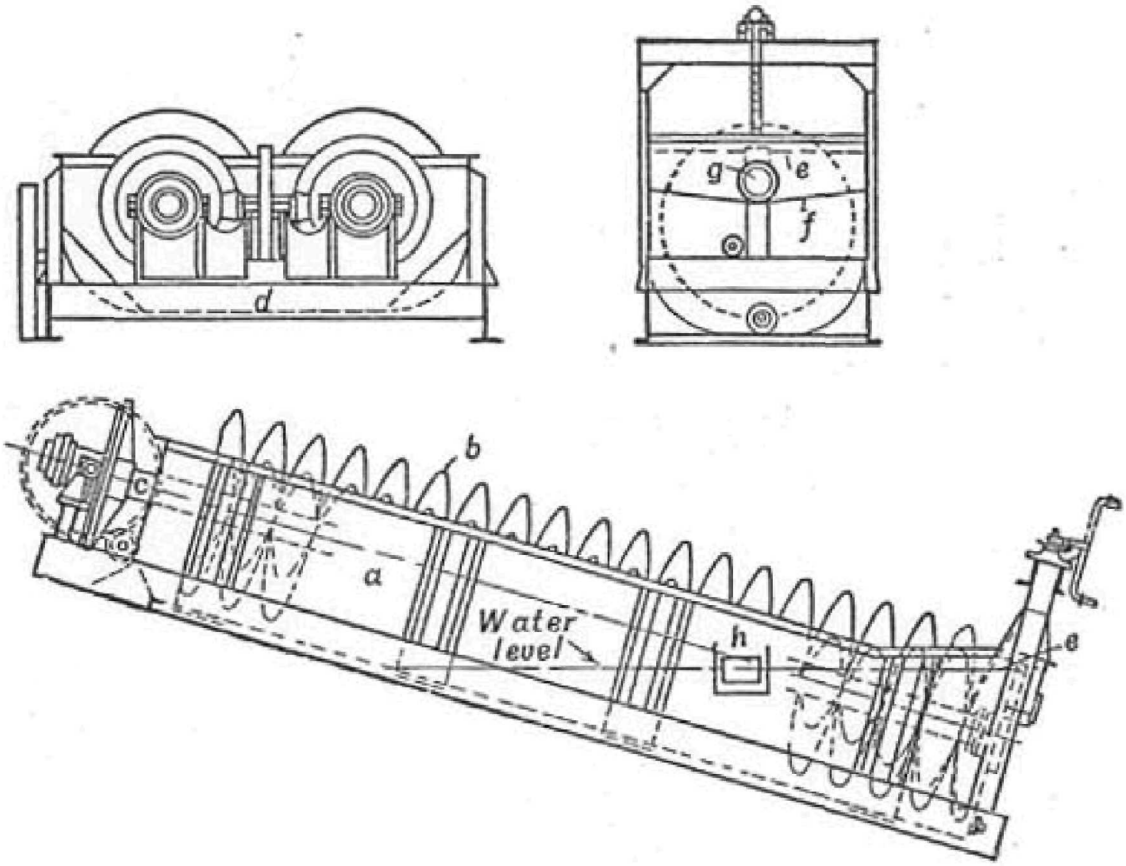


Figure 42. Technical illustration, cross-section of Agitair flotation cell

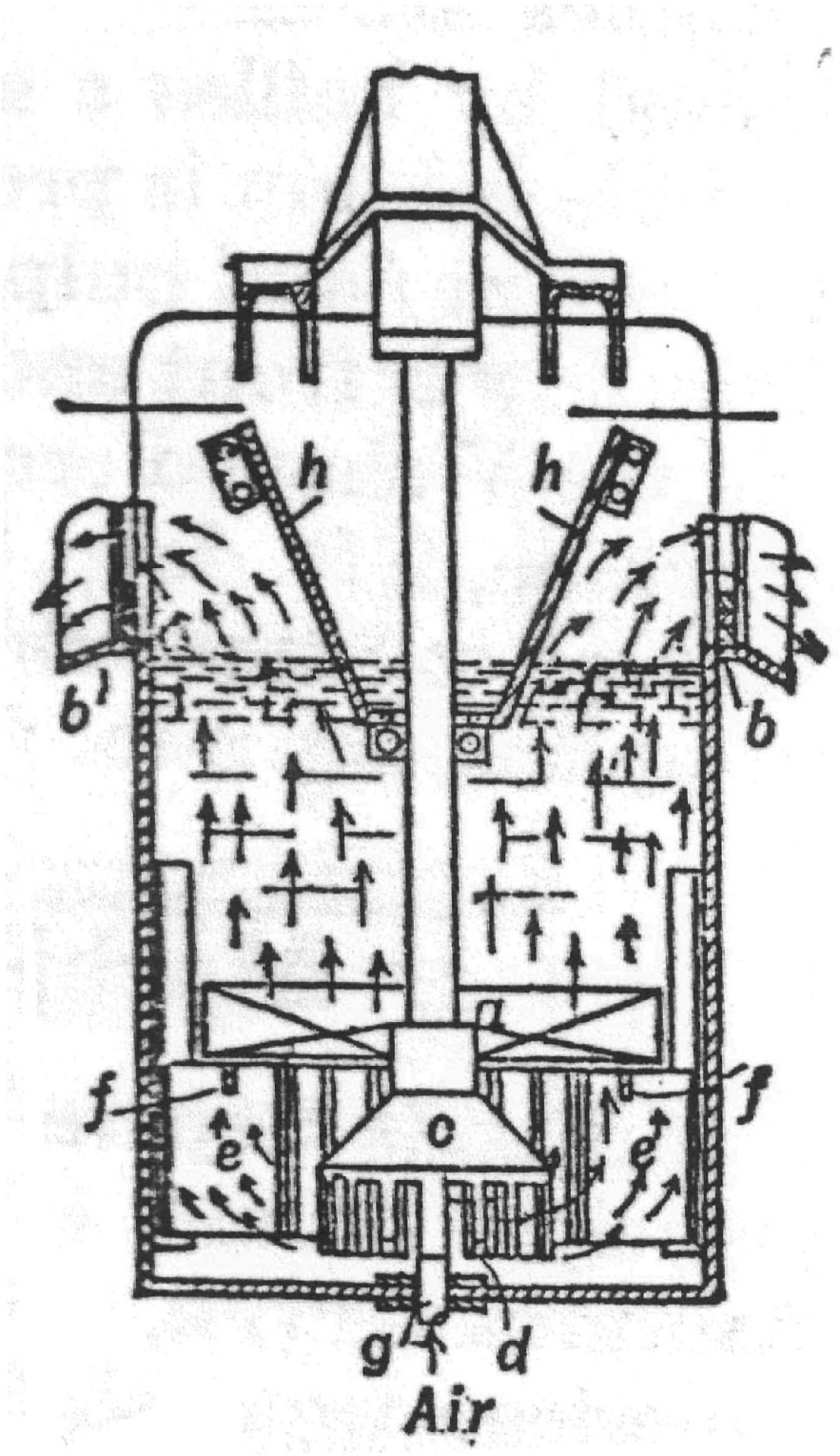


Figure 43. Historic photograph of coarse tailings being deposited on tailings pile dam, Elizabeth Mine

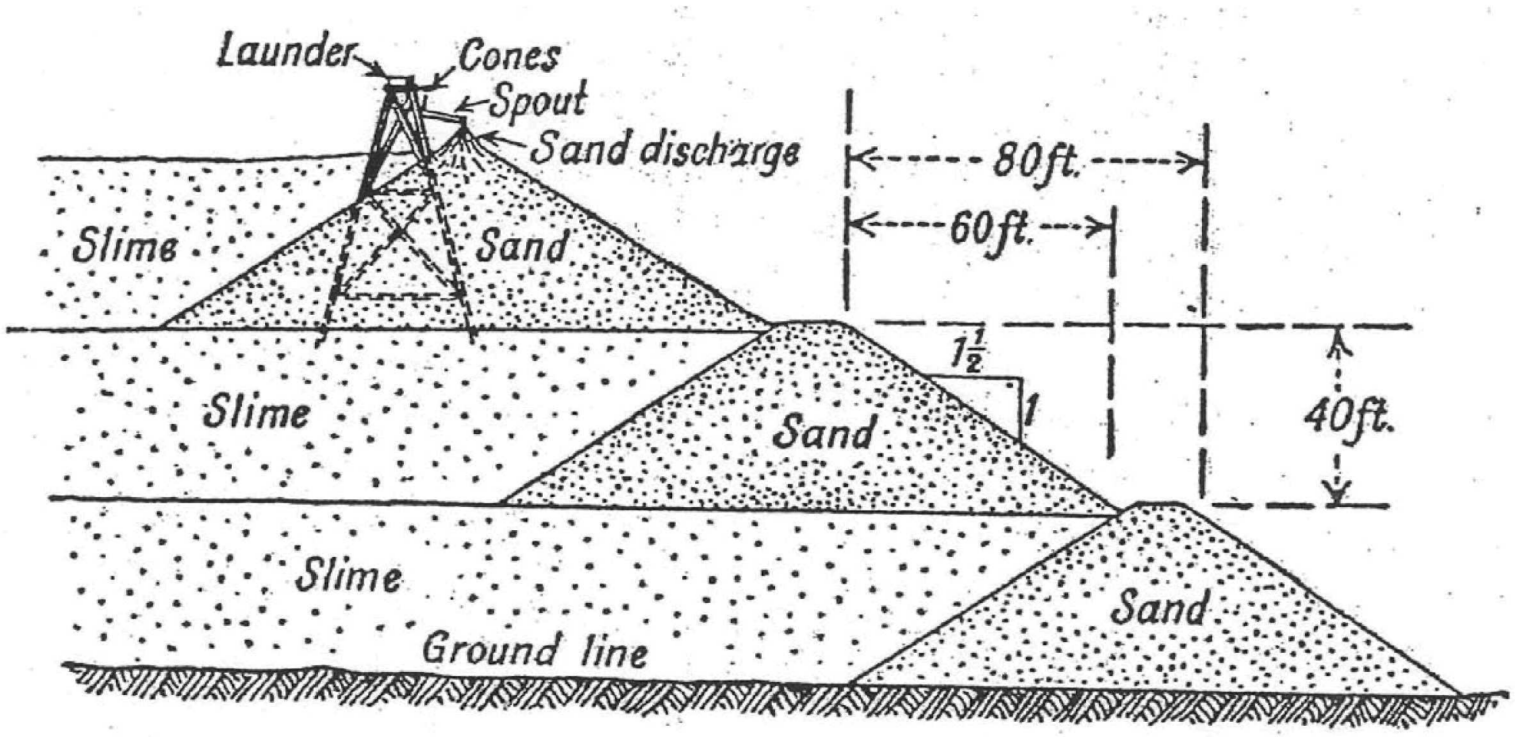
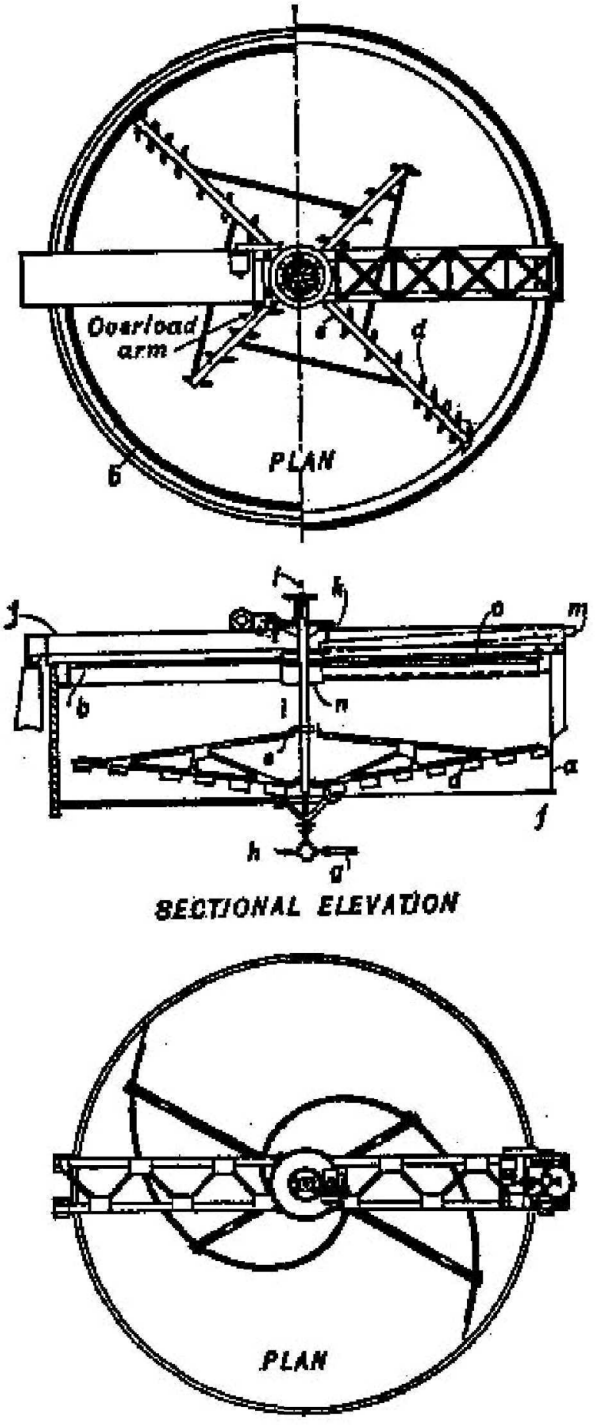


Figure 44. Schematic section of typical tailings disposal pile

Figure 45. Technical illustration of Dorr rotary rake thickener



Single-compartment rotary-rake thickener.

Figure 46. Technical illustration of Oliver continuous filter

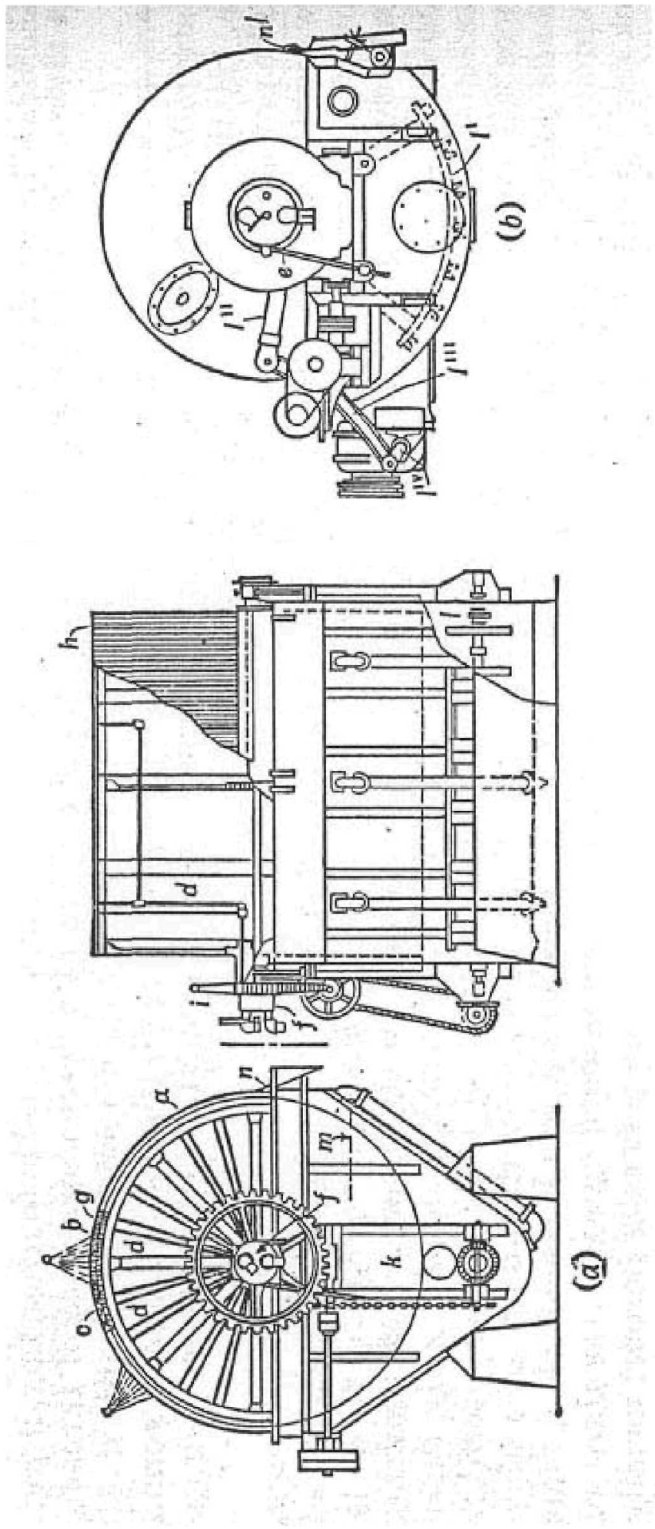
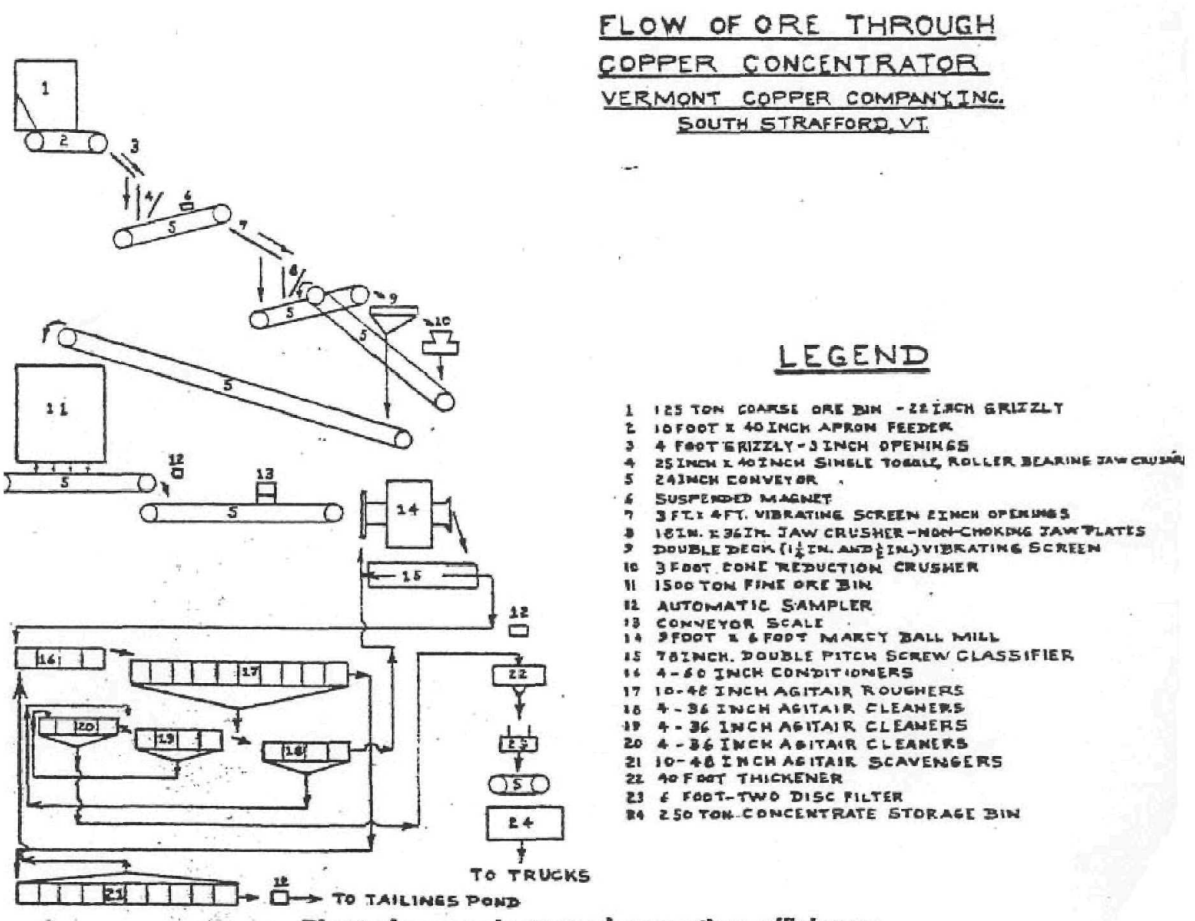


Figure 47. Mill Flowsheet, ca. 1948-1952



Plant changes improved operating efficiency

Figure 48. Technical illustration of American disc filter

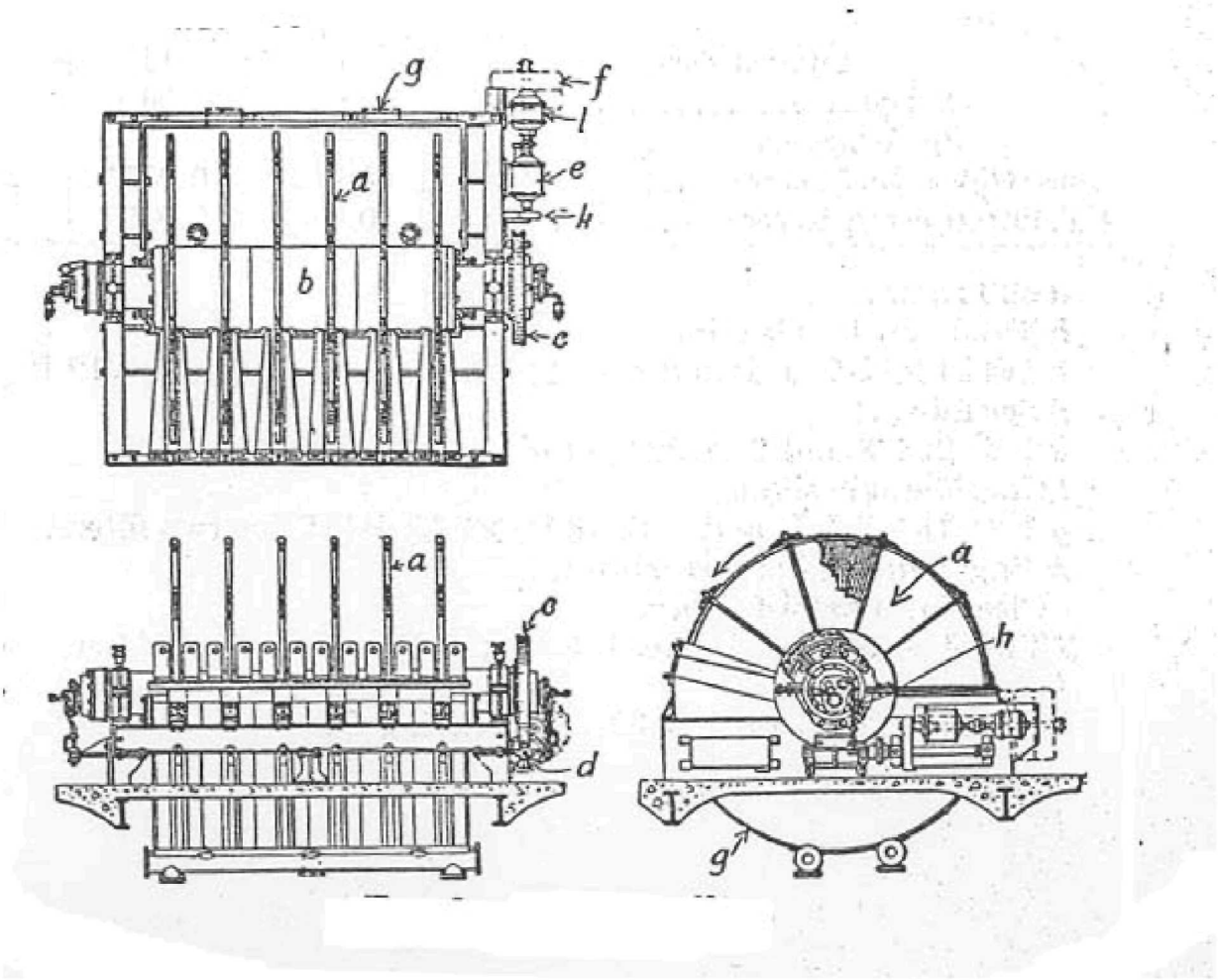
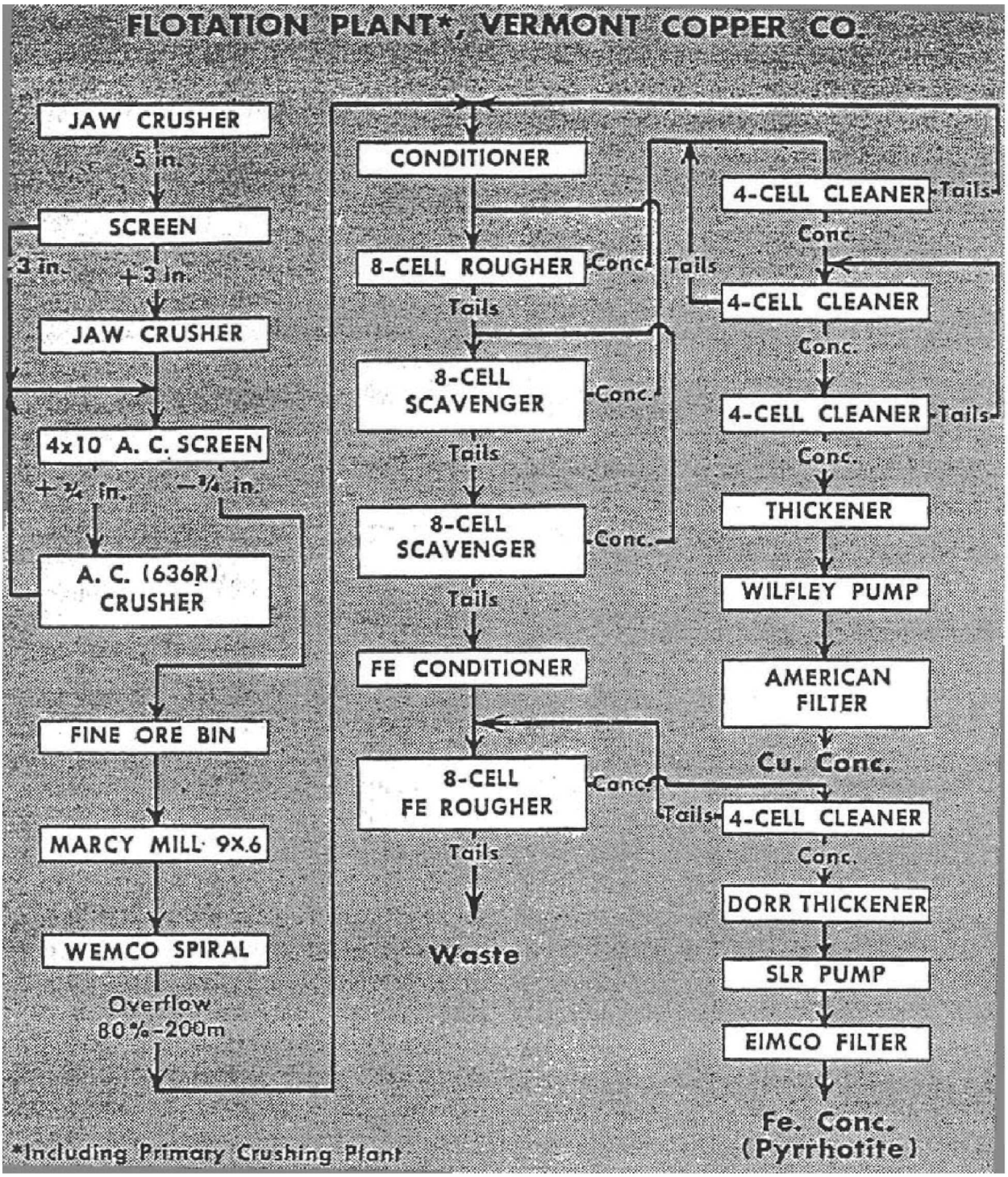


Figure 49. Mill Flowsheet, ca. 1952-1958



APPENDIX A
HAER Drawing Sheet Source Credits
(see Narrative Report Sources of Information/Bibliography for full citations)

Sheet 1: Vermont Copper Co. Inc. Elizabeth Mine 1942-1958

Location map showing Orange County Copper Belt mines (Kierstead 2000:3/15).

Generalized geological map of the Vermont Copper Belt (Seal et al. 2000:117, Figure 1).

Historic Photograph of 1898 Adit at official opening of Elizabeth Mine, 1943 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

"Plot of Buildings and Facilities at Elizabeth Mine and Copper Concentrate Processing Plant Now in Operation at South Strafford," from "Vermont Copper Company's Big Mining Enterprise Now Well Established at South Strafford, VT." Randolph, VT, Herald 14 Dec 1944.

Longitudinal section drawing of mining progress, 1957 (Kierstead 2000)(This map is a composite created by Arthur D. Little, Inc. as a report supplement. It is accurate north of the 1948 Shaft, where it was based on company records. It does not show the ultimate extent of mining south of the 1948 Shaft, which is shown in Howard 1969).

Longitudinal section drawing of mining progress as of 1958 (Howard 1969, Figure 2).

Calvert Smith Photograph Collection, Strafford Historical Society, Strafford, VT.

Sheet 2: Mine Plant Buildings

"Plot of Buildings and Facilities at Elizabeth Mine and Copper Concentrate Processing Plant Now in Operation at South Strafford," from "Vermont Copper Company's Big Mining Enterprise Now Well Established at South Strafford, VT." Randolph, VT, Herald 14 Dec 1944.

Historic photograph of Elizabeth Mine plant looking west, ca. 1950 (Collamer M. Abbott Collection, Bailey-Howe Library, Special Collections, University of Vermont, Burlington, VT).

Sheet 3: Ore Movement Through the Site

975 ft Station Layout (Benson et al. 1950:21).

Longitudinal section drawing of mining progress, 1957 (Kierstead 2000) (This map is a composite created by Arthur D. Little, Inc. as a report supplement. It is accurate north of the 1948 Shaft, where it was based on company records. It does not show the ultimate extent of mining south of the 1948 Shaft, which is shown in Howard 1969).

Longitudinal section drawing of mining progress as of 1958 (Howard 1969, Figure 2).

Schematic profile drawing of Elizabeth Mine sublevel stoping method (Benson et al. 1950:21).

Schematic section of typical shrinkage stoping method (Peele 1941:10/275, Figure 430).

Sheet 4: Ore Processing Flowsheet

Mill Flowsheet, ca. 1944-1948 (Jacobs 1944:9).

Mill Flowsheet, ca. 1948 1952 (Benson et al. 1950:22).

Mill Flowsheet, ca. 1952-1958 (Jutjen and Kearney 1953:74).

HISTORIC AMERICAN ENGINEERING RECORD

INDEX TO PHOTOGRAPHS

Elizabeth Mine HAER No. VT-35
Mine Road, (1.75 miles southeast of the intersection of
Vermont Route 132
and Mine Road in the
village of South Strafford)
Orange County
Vermont

Photographer: Rob Brewster, Warren Jagger Photography,
Providence, RI. May 2003

VT-35-1 Office/Warehouse, looking southwest

VT-35-2 Office/Warehouse, looking northwest

VT-35-3 Machine Shop/Workshop, looking southwest

VT-35-4 Machine Shop/Workshop, looking northeast

VT-35-5 Machine Shop/Workshop, looking northwest, with ruins of Compressor Building at left and Office/Warehouse at right

VT-35-6 View looking northeast showing Machine Shop/Workshop at left and ruins of Compressor Building at right

VT-35-7 Change House, looking southwest

VT-35-8 Change House, looking northeast

VT-35-9 Core Storage Shed, looking southeast

VT-35-10 Mine Foreman's Office, looking northeast

VT-35-11 1898 Adit, looking west

VT-35-12 Main Electrical Substation site, looking southeast

VT-35-13 Electrical Cable Vault, looking northwest

VT-35-14 Fuel Pumps, looking northwest

VT-35-15 Mine Car Bridge, looking southeast

VT-35-16 Mine Car Bridge, looking northwest

VT-35-17 Ball Mill Ball Bin, looking northwest

VT-35-18 1943 Jaw Crusher Base, looking southwest

VT-35-19 1943 Cone Crusher Base, looking northeast

VT-35-20 View looking northwest showing from left to right: Garage, Concentrating Mill, Heating Plant, and Thickener/Filter Building at rear

VT-35-21 View looking northwest showing from left to right: north end of Garage, Concentrating Mill, Heating Plant, and Thickener/Filter Building at rear

VT-35-22 View looking west showing from left to right: north end of Garage, Heating Plant, Concentrating Mill, and Thickener/Filter Building

VT-35-23 View looking southwest showing from left to right: north end of Garage, Heating Plant, Concentrating Mill, and Thickener/Filter Building

VT-35-24 View looking northwest showing Concentrating Mill at center and Thickener/Filter Building at right

VT-35-25 View looking west showing Concentrating Mill at center and Thickener/Filter Building at right

VT-35-26 Concentrating Mill looking south

VT-35-27 Interior view of grinding section of Concentrating Mill looking northwest showing footings for 6-foot by 9-foot Marcy ball mill at right and 72-inch Wemco spiral classifier at left

VT-35-28 Interior view of grinding section of Concentrating Mill looking south

VT-35-29 Thickener/Filter Building looking southwest

VT-35-30 Thickener/Filter Building looking southeast over foundation of 1952 Pyrrhotite Thickener Building

VT-35-31 Tailings Pump House looking northwest

VT-35-32 Garage looking northwest

VT-35-33 Heating Plant looking northwest

VT-35-34 Heating Plant looking southeast

VT-35-35 Fire Hose House (typical) looking northwest

VT-35-36 Assay Laboratory looking northeast

VT-35-37 Assay Laboratory looking southwest

VT-35-38 Lower Water Tank Building looking northeast

VT-35-39 Lower Water Tank Building looking southwest

VT-35-40 Electrical Shop looking southeast

VT-35-41 "Copper Castle" looking northwest

VT-35-42 1948 Shaft Hoist House foundation looking southwest

VT-35-43 1948 Shaft Collar site looking northwest

VT-35-44 Infirmary/Carpenter Shop looking southwest

VT-35-45 Boarding House/Club House looking northeast

VT-35-46 Community Center/Chapel looking south

VT-35-47 Ompompanoosuc River Pumphouse ruins looking northwest

VT-35-48 Air Shaft looking southeast

VT-35-49 Ompompanoosuc River Electrical Substation looking south

VT-35-50 South Open Cut looking north from south end

VT-35-51 South Open Cut looking north from opposite crosscut

VT-35-52 South Open Cut looking south from near north end

VT-35-53 Copperas Works site looking northwest

VT-35-54 Copperas Works site looking northwest

VT-35-55 North Open Cut looking north from midpoint

VT-35-56 North Open Cut looking south from north end

VT-35-57 1880s Tyson mine dump area looking northeast

VT-35-58 Tailings Pile 1 looking west from below east end of north slope

VT-35-59 Tailings Pile 1 looking south from below northeast corner

VT-35-60 Tailings Pile 1 looking northeast from below west slope

VT-35-61 Top of Tailings Pile 1 looking northeast from Tailings Pile 2

VT-35-62 Top of Tailings Pile 1 looking northeast from east edge

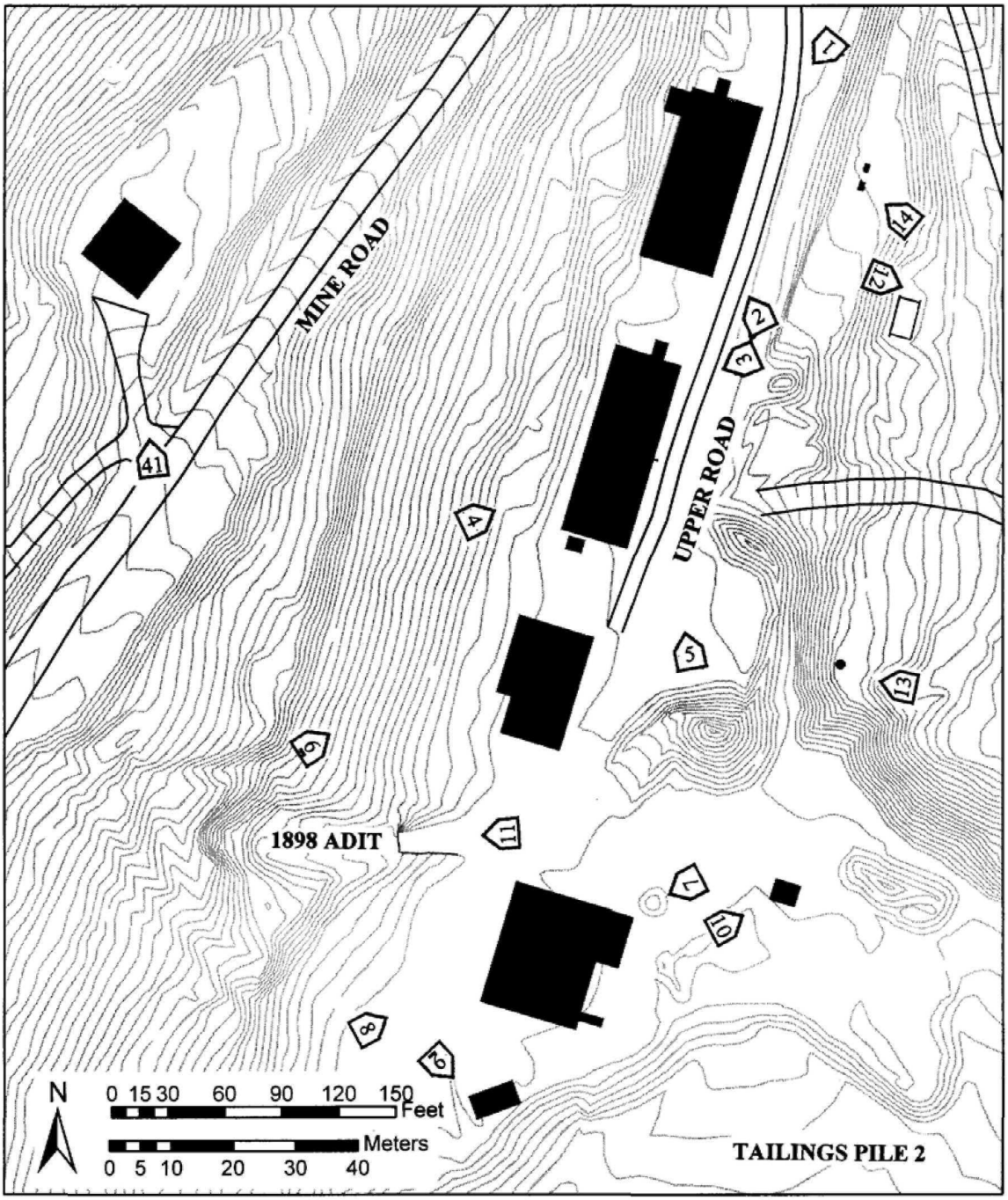
VT-35-63 Northeast face of Tailings Pile 2 looking southwest from top of Tailings Pile 1

VT-35-64 Northeast face of Tailings Pile 2 looking southeast from north end

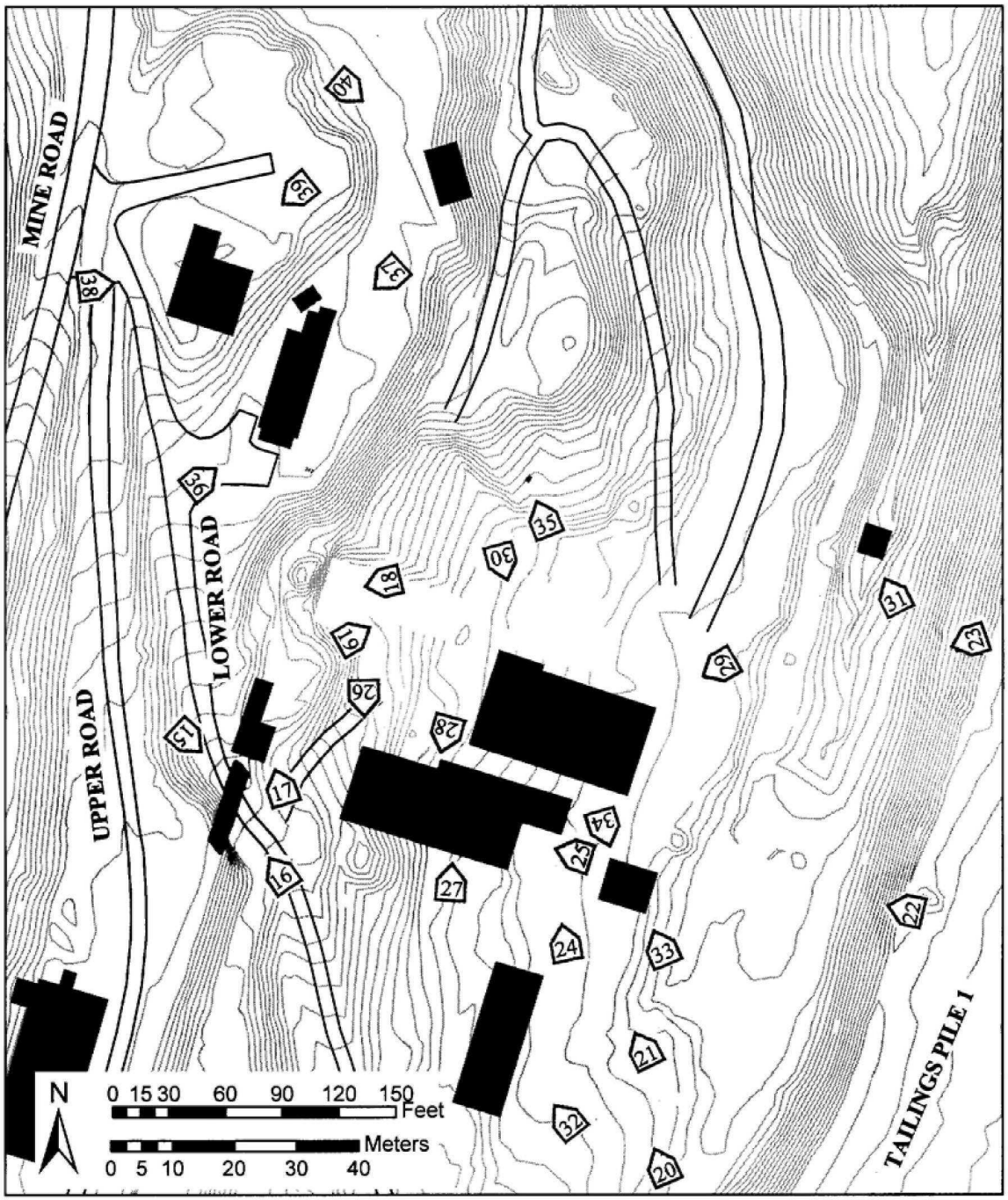
VT-35-65 Washout in northeast face of Tailings Pile 2 looking north from east edge of Tailings Pile 2

VT-35-66 Tailings water decant pipe system in washout at east side of Tailings Pile 2 looking southwest

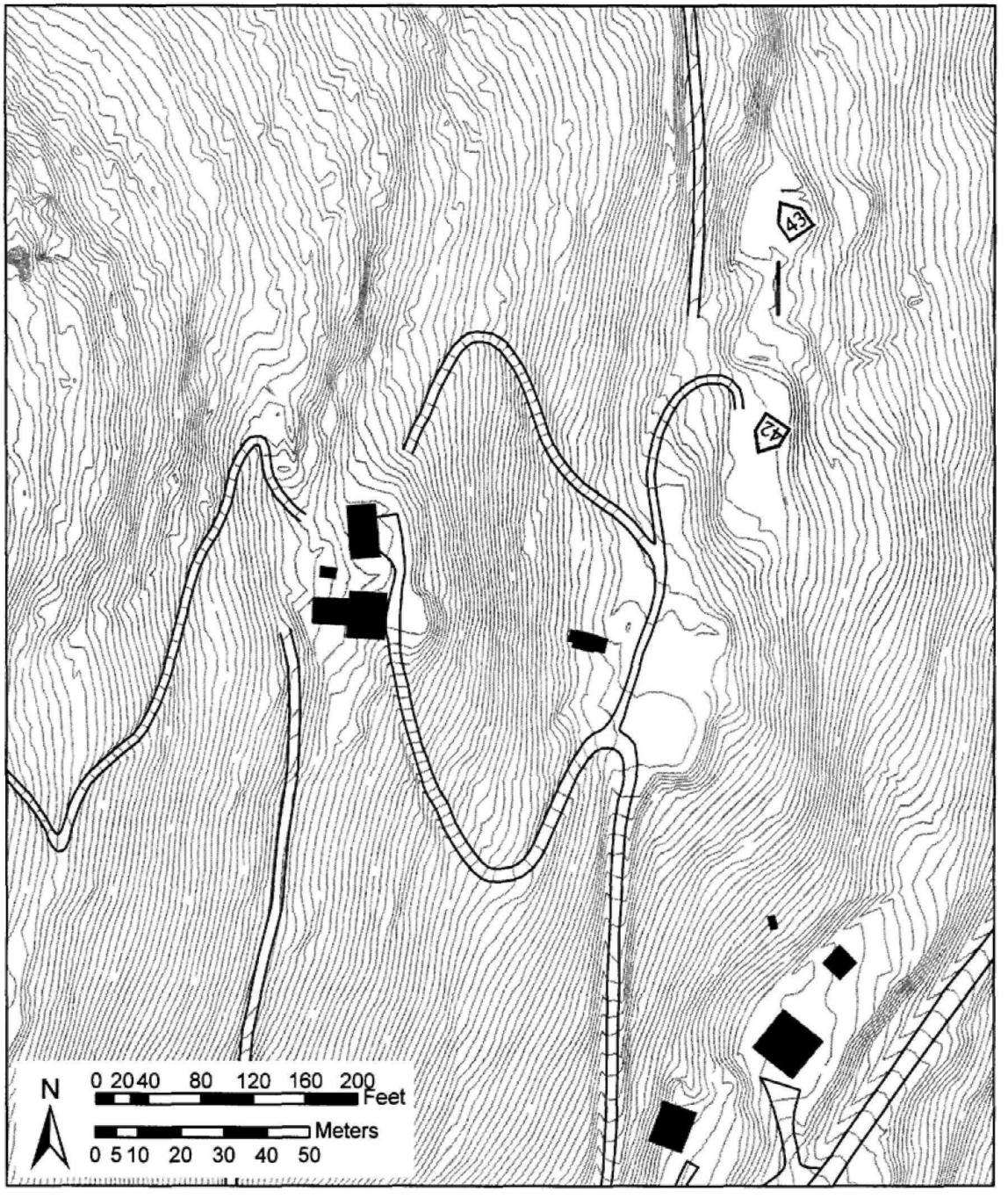
Upper Tier Buildings



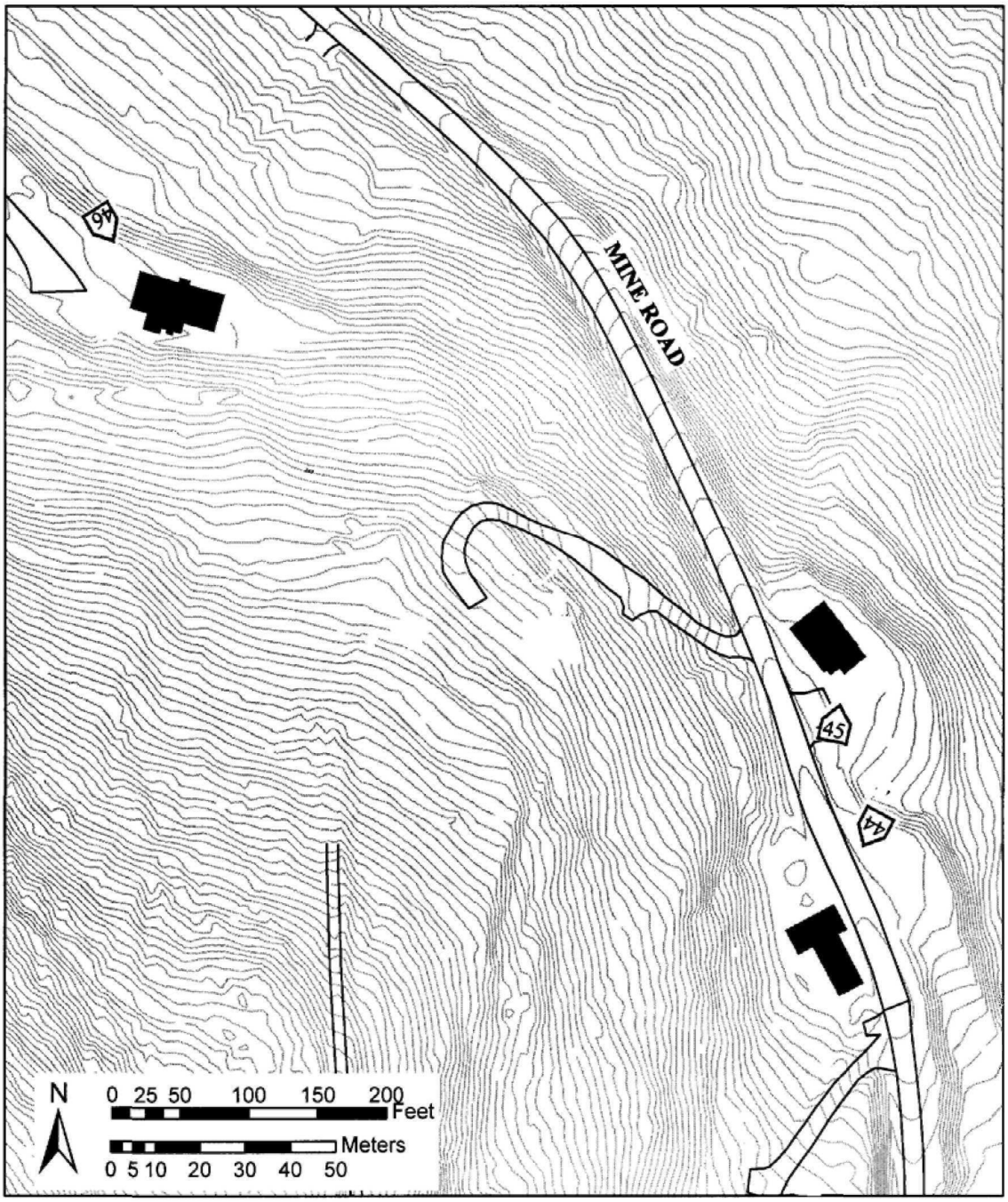
Lower Tier Buildings



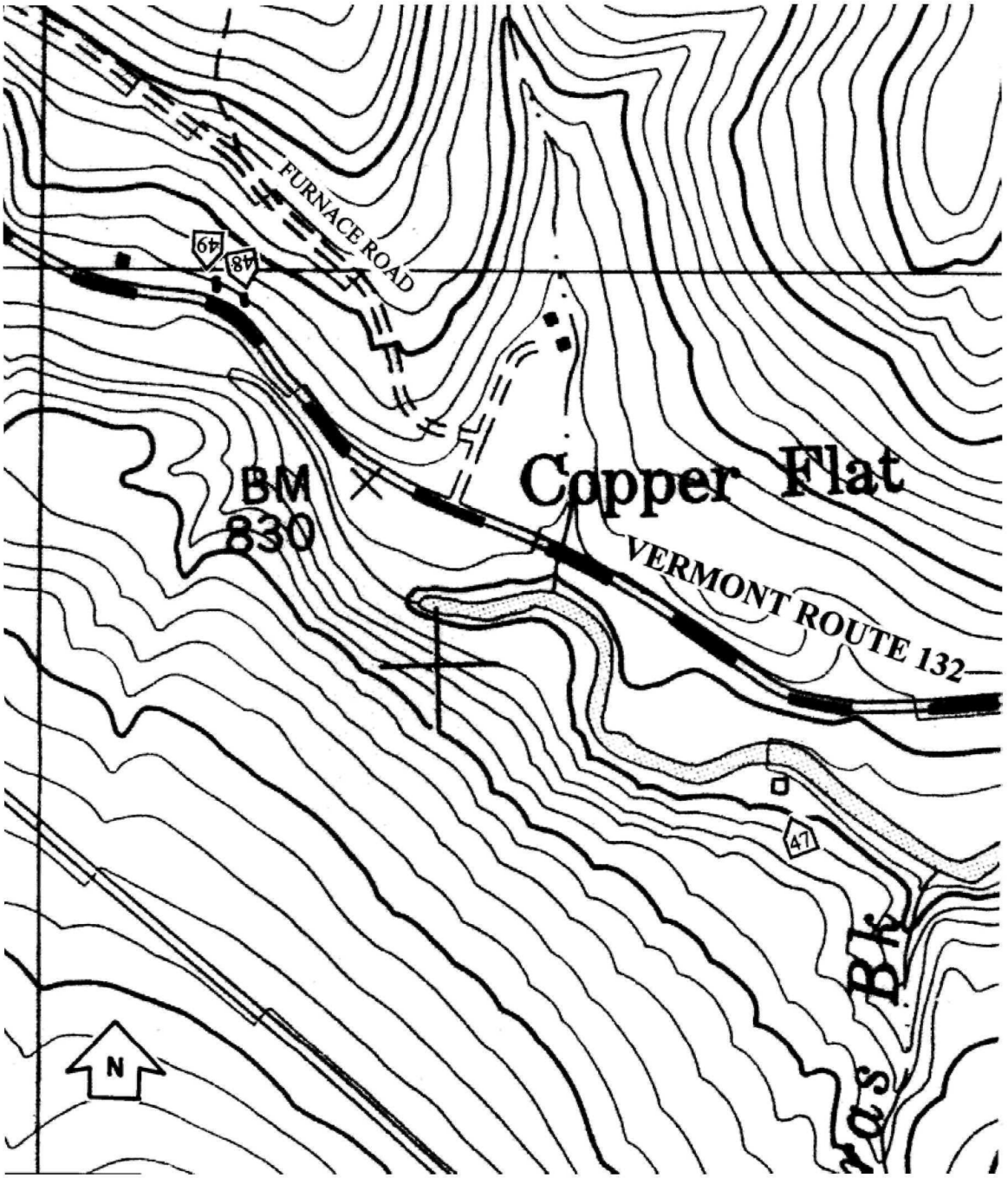
1948 Shaft Site



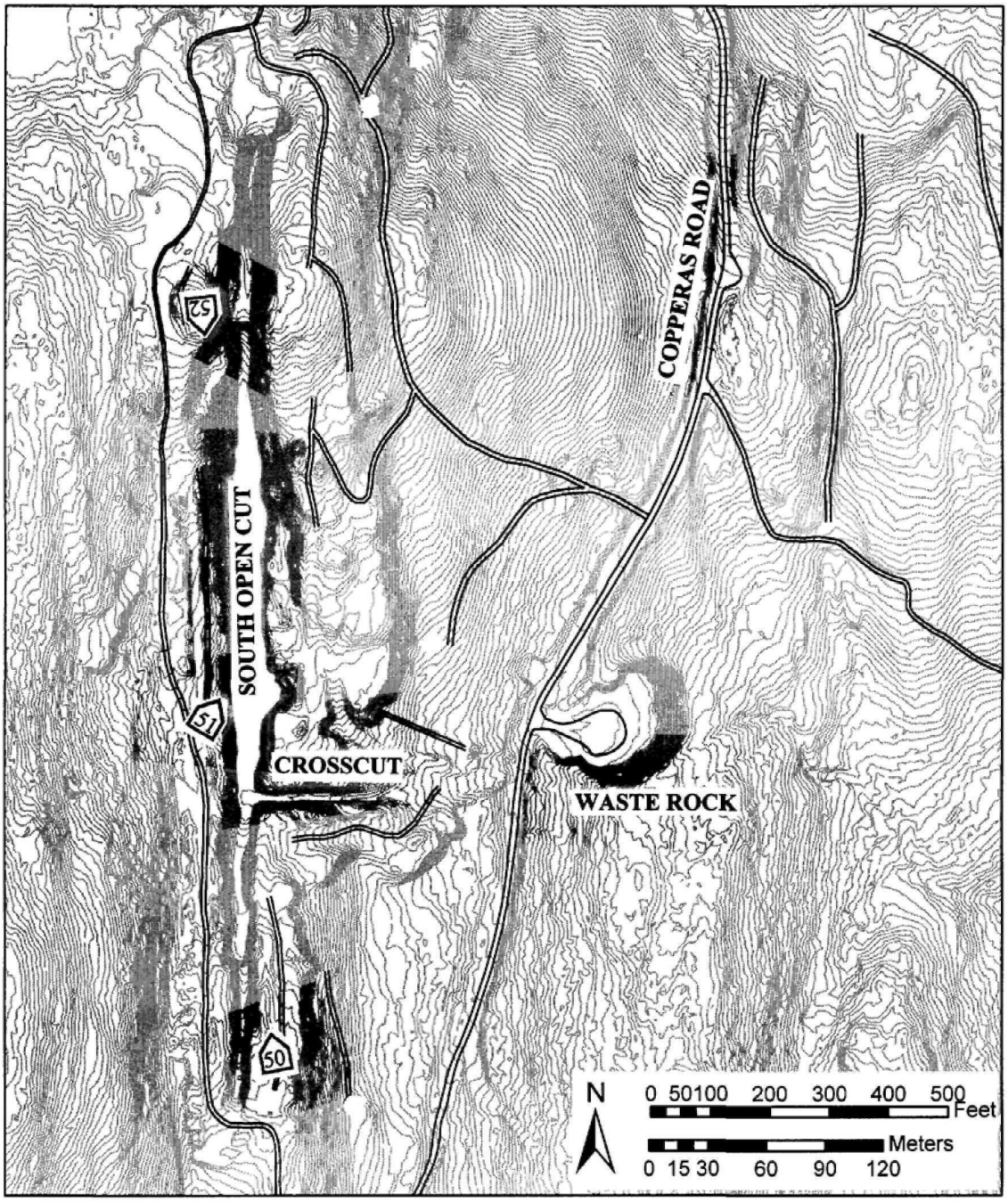
Mine Road Buildings



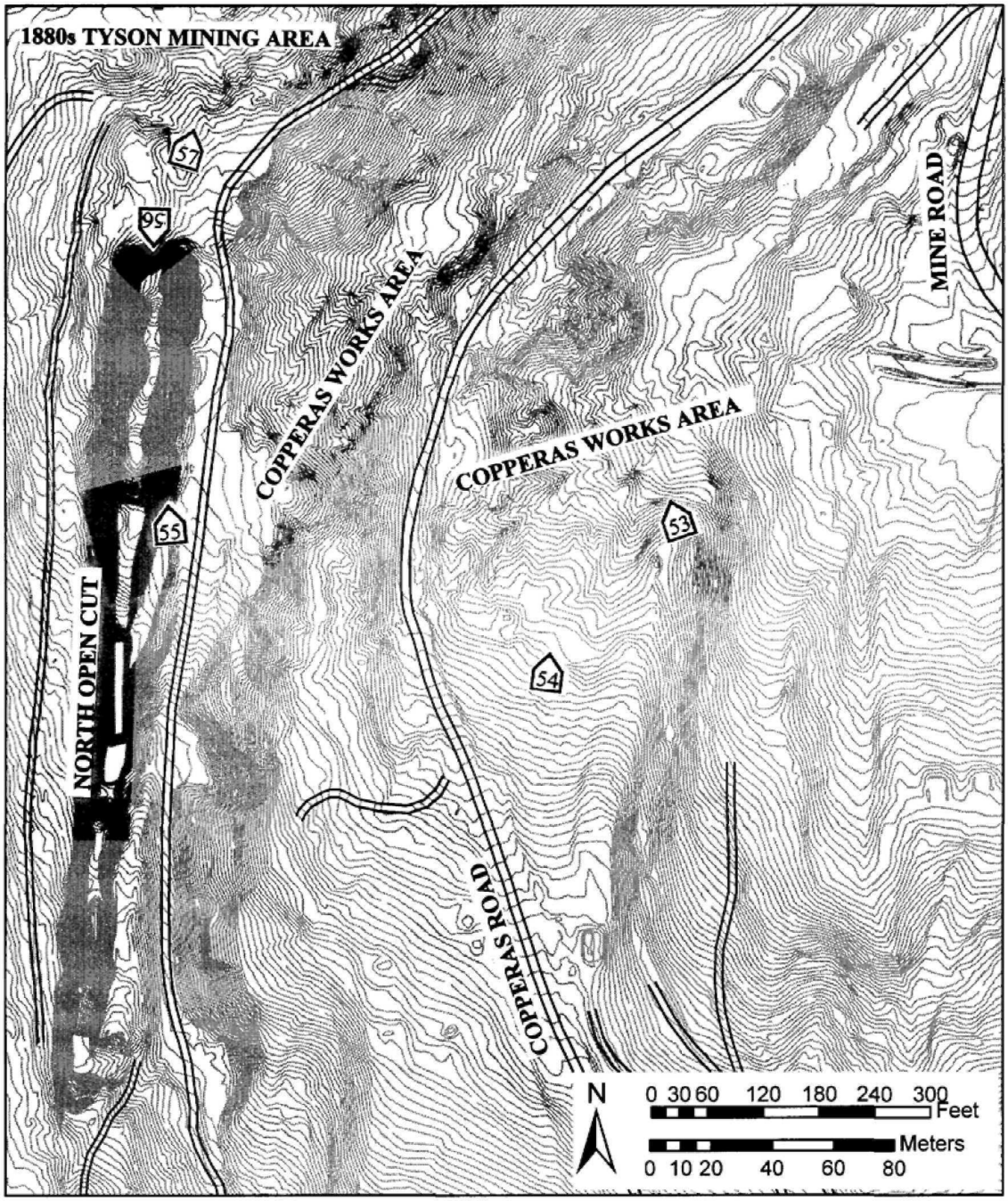
Furnace Flats Vicinity



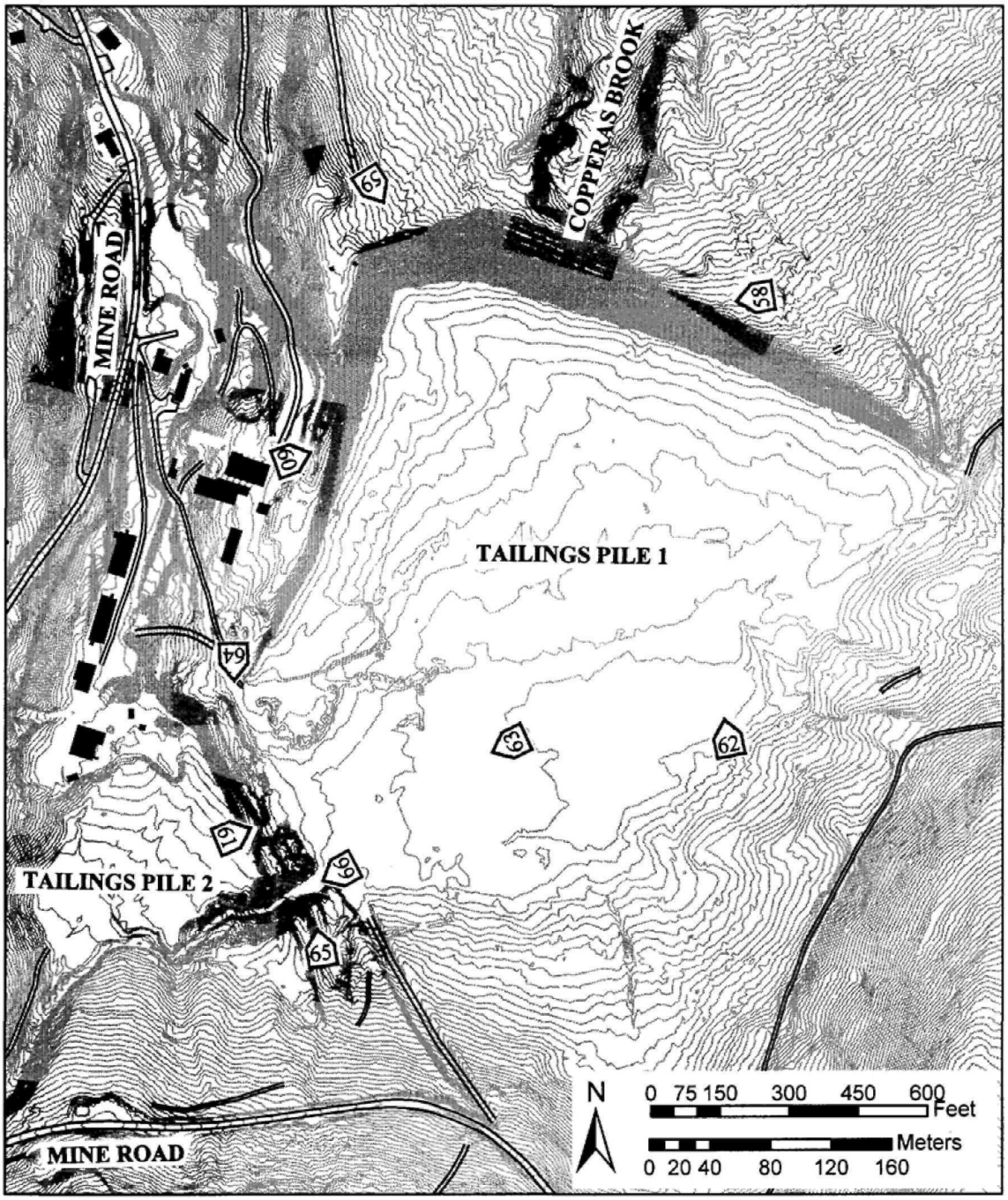
South Open Cut

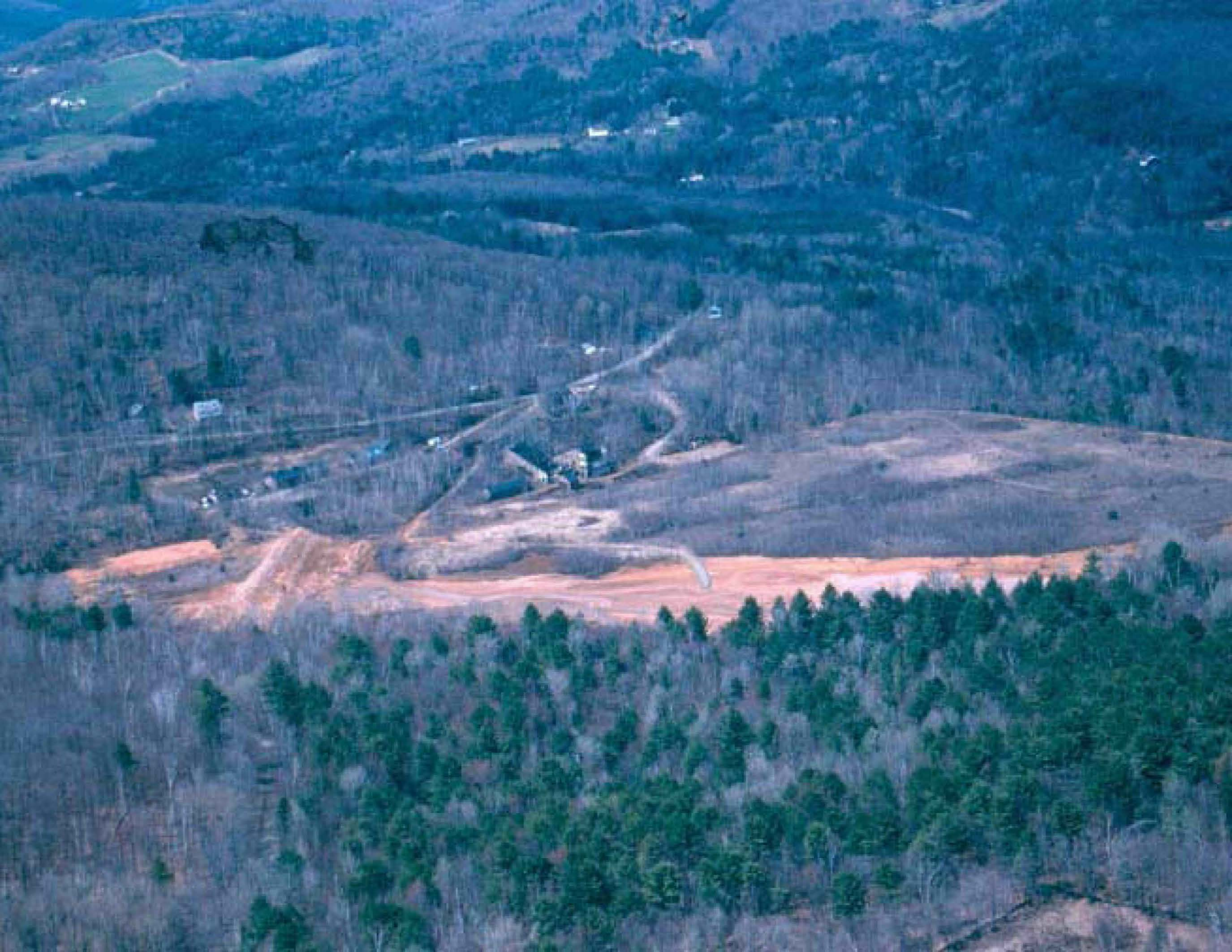


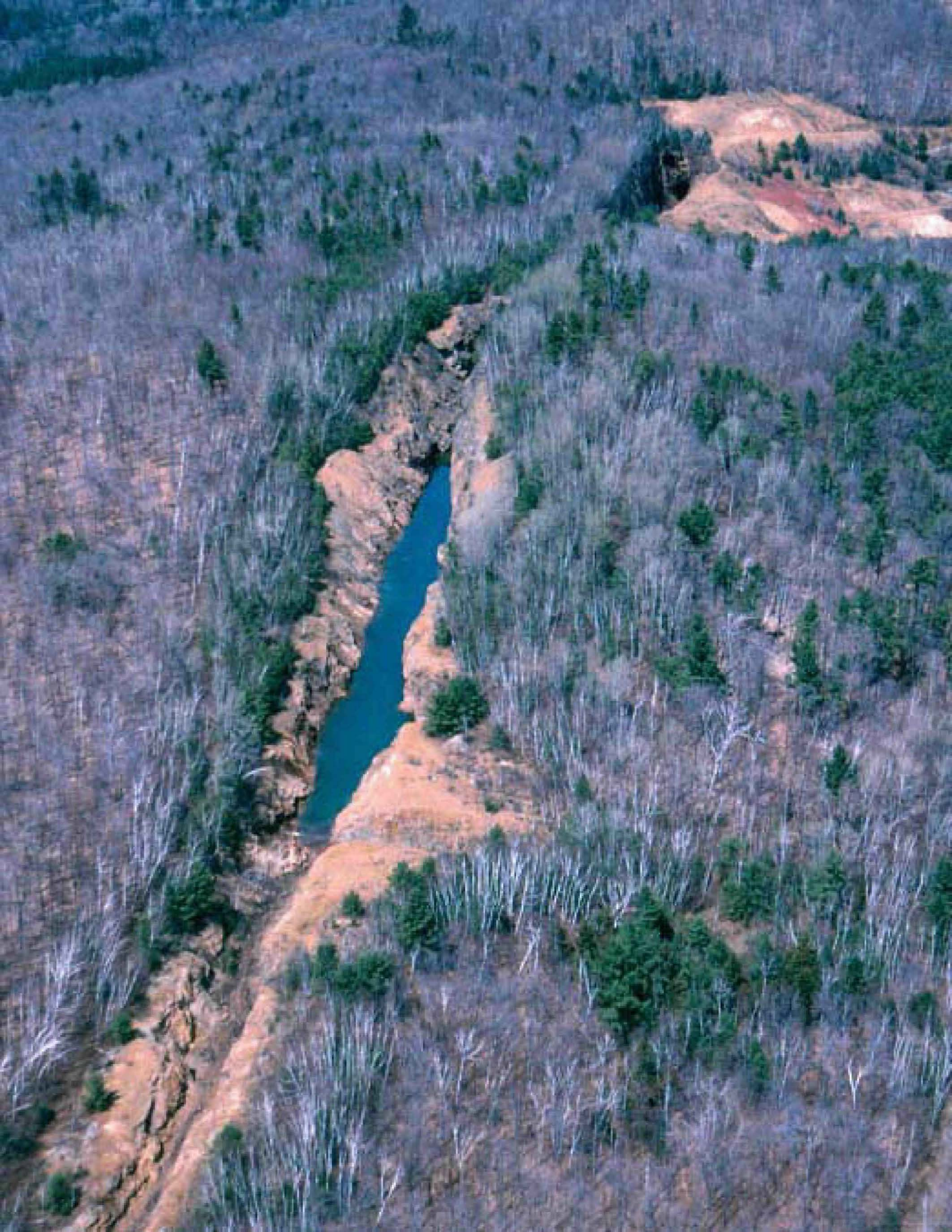
Copperas Works Area and North Open Cut

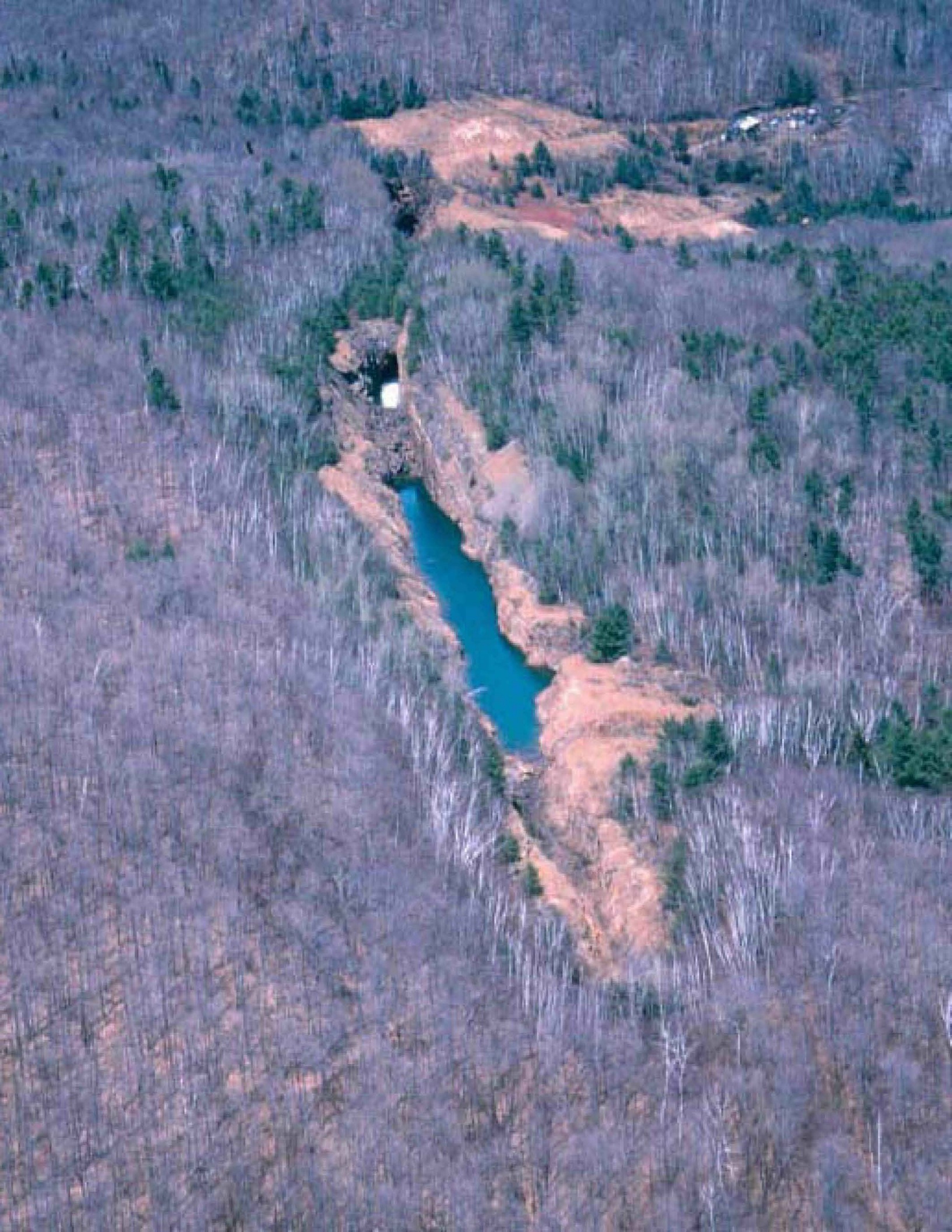


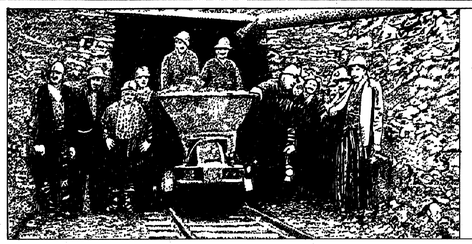
Tailings Pile 1 and Tailings Pile 2





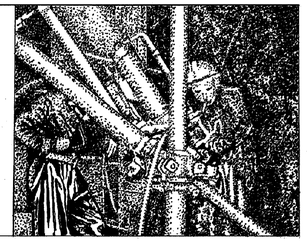






1942 VERMONT COPPER CO. INC. 1958

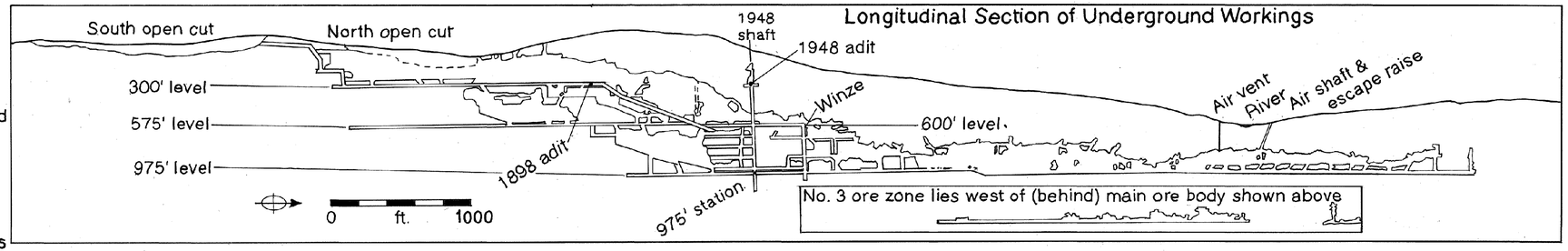
ELIZABETH MINE

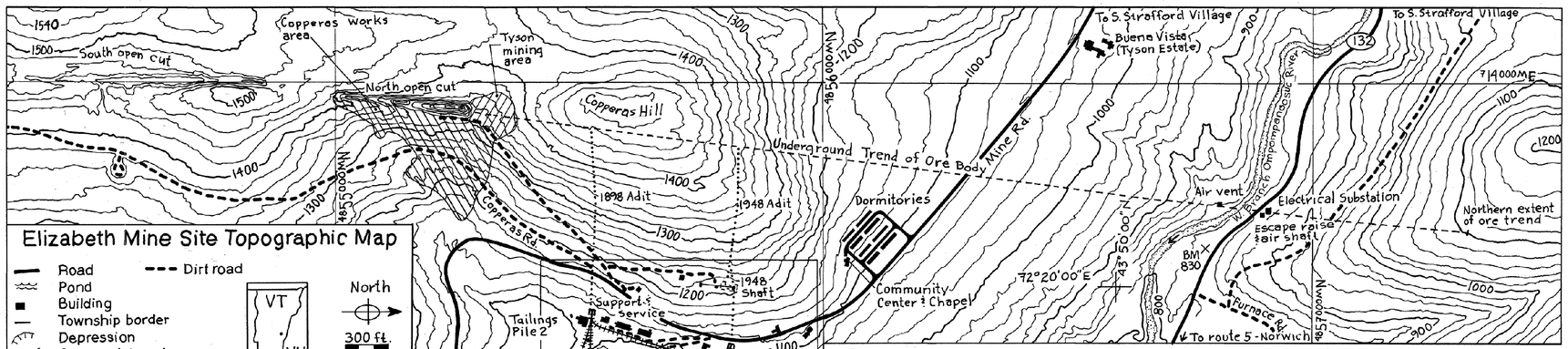


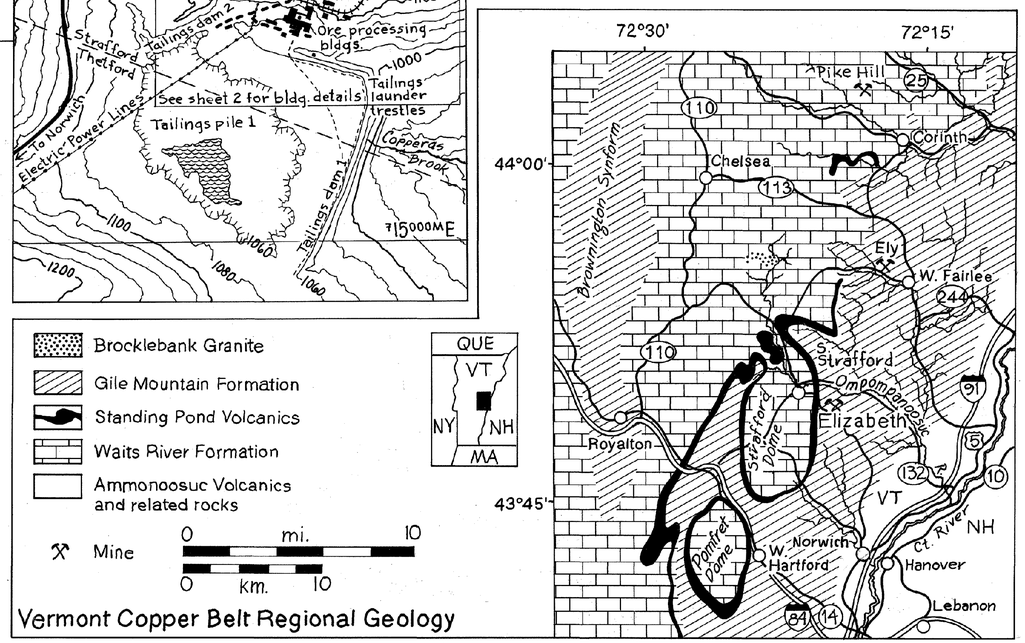
The Elizabeth Mine is the southernmost mine in the 20-mile long Orange County, Vermont, Copper Belt, a series of copper-bearing Appalachian Sulfide-type ore deposits that includes the Ely Mine at Vershire and the Pike Hill mines at Corinth. The Elizabeth Mine ran almost continuously from 1809 to 1958, and produced the highest tonnage of copper of the three mines. It was also an important domestic source of copperas, an iron sulfate chemical, from 1809 to 1882. Copper was smelted on site in several brief campaigns between 1830 and 1919. The mine was most productive between 1943 and 1958 when it was revived using modern technology. After entry into World War II the U.S. government assisted development of the Elizabeth Mine as a strategic source of copper. The Vermont Copper Company, Inc., organized in April 1942, was awarded a contract with the Reconstruction Finance Corporation, and reopened the mine. The project included building a twelve-mile paved highway, miners' housing, and restoring an 1898 mine entrance. The Galigher Company of Salt Lake City, UT, built the core complex of ore processing and support buildings on Mine Road. Underground mining resumed in spring, 1943. The ore was concentrated on site, trucked to Norwich, VT, and sent from there by rail to a Phelps-Dodge Copper Co., smelter at Laurel Hill, Long Island, NY. After the war, productivity was hampered by low ore volume and technical problems, and the mine did not turn its first profit until 1949.

Underground mining methods were changed to increase output, and milling equipment was improved to handle more ore and extract more copper. Surface ore from the South Open Cut and old ore dumps supplemented underground ore. In 1950 the mine reached a production high of 7 million lbs., which coincided with a rise in price and demand for copper during the Korean War. Efforts to exploit other values in the ore took place in 1952, when sulfur shortages prompted installation of equipment to extract 25,000 tons per year of pyrrhotite (iron sulfide) from mill tailings. This material was purchased by the Brown Paper Company of Berlin, NH, which extracted sulfur for treating wood pulp. Ultimately matching and tuning of mining practices and processing equipment resulted in a production peak of 800 tons per day, and exploitation of the iron byproduct added to profits. Prices fell after the Korean War, but U.S. Government contracts kept the mine operating. In June 1954, the mine was purchased by Appalachian Sulphides, Inc., a Canadian mining company. The mid-1950s were highly productive years. Annual production exceeded 8.5 million lbs. in 1954 and 1955. Employment reached a high of 220 and sales exceeded $3 million. However, by 1956, as underground workings progressed north of the Ompompanoosuc River, the grade and quantity of ore diminished. Copper was in oversupply and prices fell from a 90-year peak. In February 1958, Appalachian Sulphides closed the Elizabeth Mine in favor of reopening a similar copper sulfide mine at Ore Knob, NC. When the Elizabeth Mine closed underground workings extended approximately 7,500 ft and included about 5 miles of tunnels. Between 1946 and 1956 the mine was among the top 25 copper producers in the U.S. The 1943-1958 mining campaign yielded approximately 91.5 million lbs. of copper, and total lifetime output for the Elizabeth Mine is estimated at over 100 million lbs.

Consult the Appendix for the Narrative Report for source credits for all 4 drawings







Vermont Copper Belt Regional Geology

DATA COMPILED BY MATT KIERSTEAD, INDUSTRIAL HISTORIAN, PUBLIC ARCHAEOLOGY LABORATORY, PAWTUCKET, RI

DELINEATED BY: DENNIS O'BRIEN, ILLUSTRATOR, MYSTIC CT 12/2003

ELIZABETH MINE RECORDING PROJECT

UNITED STATES DEPARTMENT OF THE INTERIOR NATIONAL PARK SERVICE

VERMONT COPPER COMPANY, INC. ELIZABETH MINE 1942 - 1958

MINE ROAD

SOUTH STRAFFORD STRAFFORD THETFORD TOWNSHIPS ORANGE COUNTY VERMONT

HISTORIC AMERICAN ENGINEERING RECORD

SHEET 1 of 4

IF REPRODUCED, PLEASE CREDIT: HISTORIC AMERICAN ENGINEERING RECORD, NATIONAL PARK SERVICE, NAME OF DELINEATOR, DATE OF THE DRAWING

ELIZABETH MINE

Mine Plant Buildings

The center of 1942–1958 operations was the complex of World War II-era buildings on Mine Road, constructed to wartime emergency standards and of functional design.

1898 and 1948 Adits: horizontal entrances for electrified underground mine cars for transporting miners and ore.

1948 Shaft: vertical shaft serving the 1948 Adit and descending to the 975 ft level. An electric hoist raised and lowered men, ore, and equipment in three separate shaft compartments.

Office/Warehouse Building: main administrative building for the mine. Housed the receptionist, secretary, geologists and mine engineers; also a warehouse for mine equipment.

Assay Laboratory: for analysis of ore from the mine and concentrating process to control mining and flotation chemistry to maximize efficiency and copper concentrate production.

Machine Shop/Workshop: equipment maintenance and repair shop for the mine. A mine car spur track led into the building, providing service for underground equipment. A blacksmith forge and machine tools made the mine self-sufficient for most needs.

Compressor Building: supplied compressed air for pneumatic rock drills and equipment.

Change House: where mine employees changed into waterproof clothing and steel-toed boots, picked up helmets with lamps, and showered at the end of their shifts.

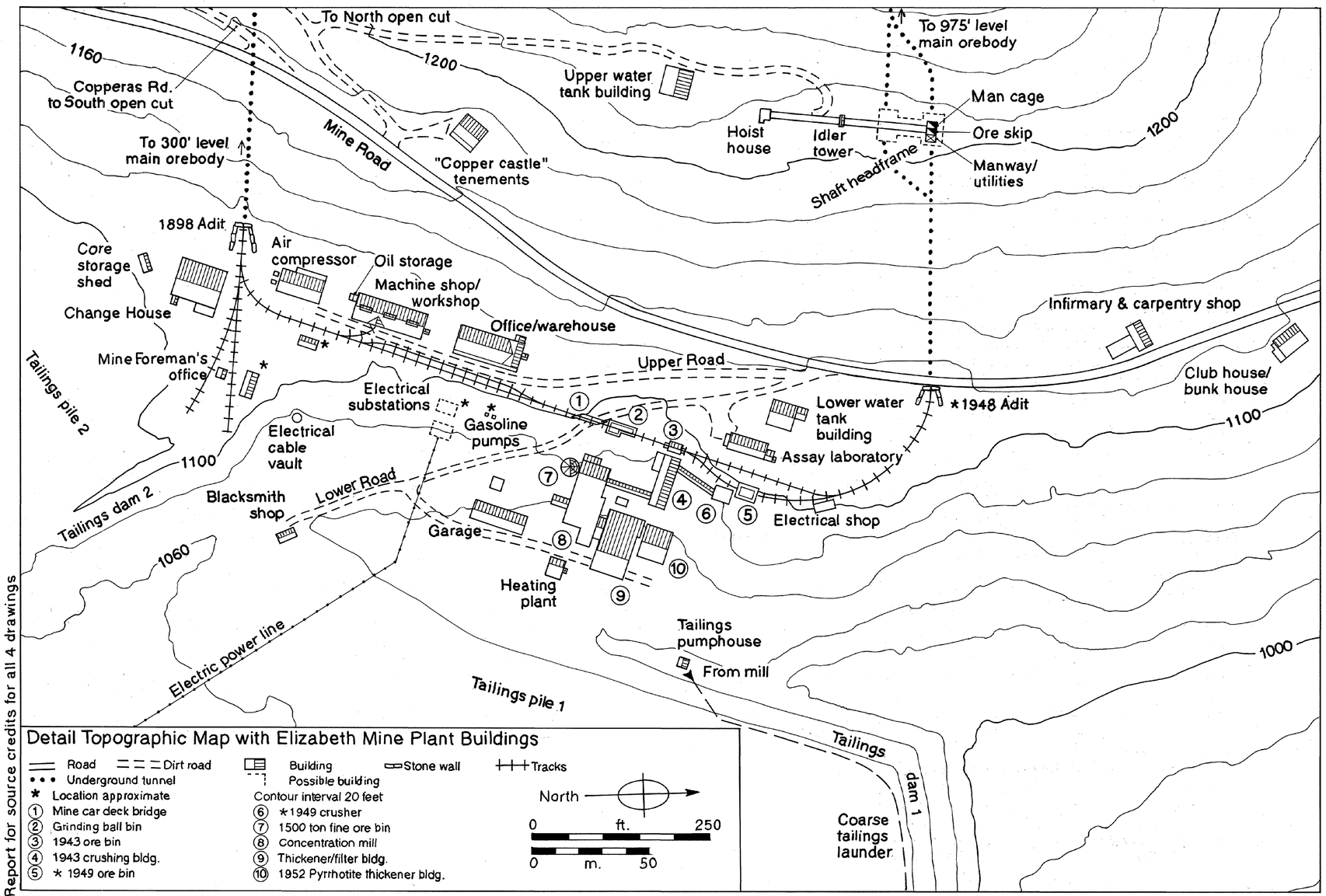
Crushers: for breaking ore into smaller pieces before it was conveyed to the ore storage bins.

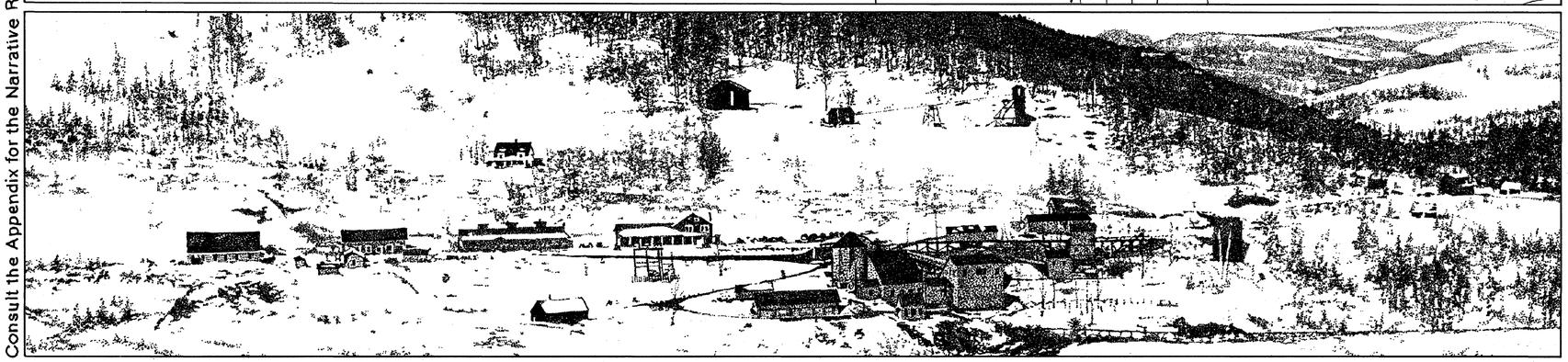
Concentrating Mill: where crushed ore was finely ground and separated into concentrate and tailings by a flotation process. Copper tailings were pumped to Tailings Pile 1.

Thickener/Filter Building: contained equipment for removing water from ore concentrate and bins for storing it before shipment to the smelter.

Pyrrhotite Thickener Building: housed the thickener for pyrrhotite processing. Pyrrhotite tailings were pumped to Tailings Pile 2.

Water Tank Buildings: sheltered large heated tanks supplying water to the Concentrating Mill. A water level indicator board was located outside each building and was visible from the Mill.





Consult the Appendix for the Narrative Report for source credits for all 4 drawings

DELINEATED BY: DENNIS O'BRIEN, ILLUSTRATOR, MYSTIC, CT 12/2003 DATA COMPILED BY MATT KIERSTEAD, INDUSTRIAL HISTORIAN, PUBLIC ARCHAEOLOGY LABORATORY, PAWTUCKET, RI

ELIZABETH MINE RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

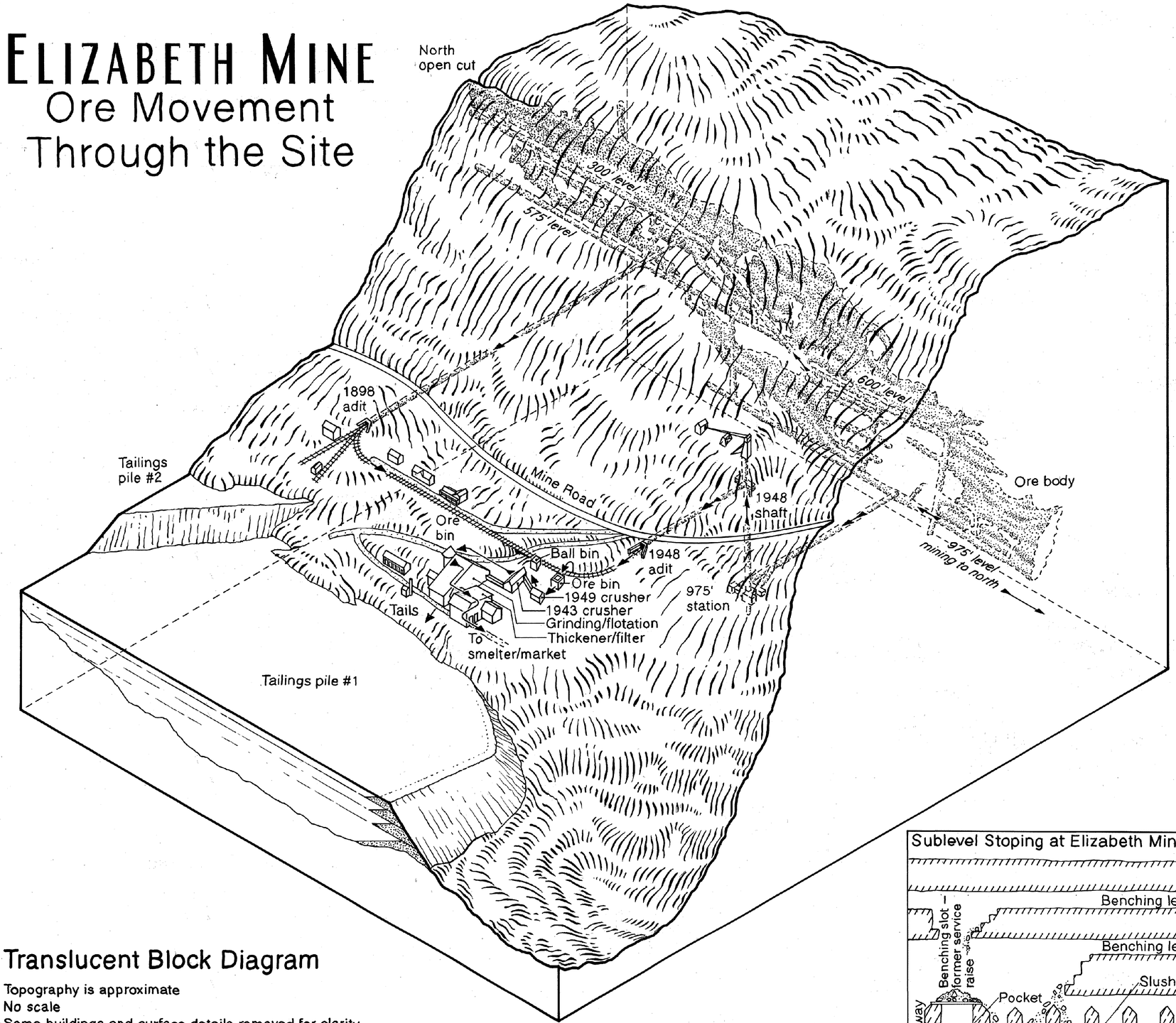
VERMONT COPPER COMPANY, INC. ELIZABETH MINE 1942 - 1958
MINE ROAD
SOUTH STRAFFORD STRAFFORD/THETFORD TOWNSHIPS ORANGE COUNTY VERMONT

HISTORIC AMERICAN ENGINEERING RECORD

SHEET 2 of 4

IF REPRODUCED, PLEASE CREDIT: HISTORIC AMERICAN ENGINEERING RECORD, NATIONAL PARK SERVICE, NAME OF DELINEATOR, DATE OF THE DRAWING

ELIZABETH MINE
Ore Movement Through the Site

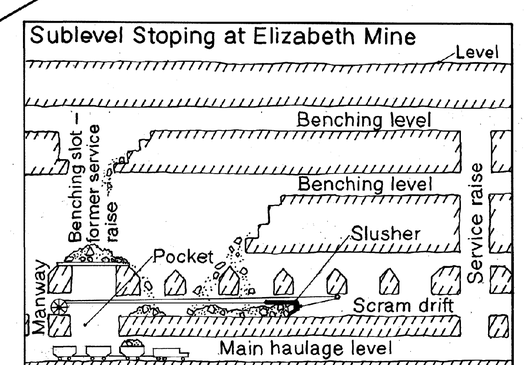


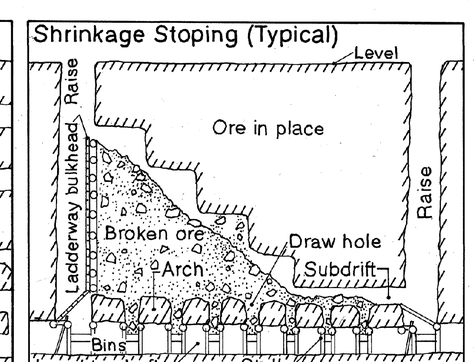
The Elizabeth Mine orebody is a north-south trending deposit that plunges north and dips east. It was first surface mined from the North Open Cut, and then underground via a series of shafts and adits (tunnels) to the north. Mining progressed north and deeper along a series of longitudinal levels, numbered in feet of depth below the surface at the North Open Cut.

In 1943 underground access to the orebody was via the 1,360 ft long 1898 Adit, which met the ore at the 300 ft level. This adit was enlarged and a room blasted for a hoist to pull mine cars up an 830 ft long inclined tunnel from the 575 ft level. During the 1940s mining progressed north and south of the 1898 Adit. By 1948 hauling ore almost 2,000 ft to the 1898 Adit had become inefficient. Exploratory drilling revealed large quantities of ore extending to the north. In 1948 a new adit and shaft were constructed to efficiently reach this ore. The 1948 Shaft descended to the 300 ft level where it met the new adit and continued down to the 975 ft station, where a tunnel extended west to the orebody. At the 975 ft station mine cars dumped ore into a skip hoist for the trip up the shaft to the 300 ft level where it was transferred to mine cars bound for the crusher.

The new workings allowed major production increases. By 1954, mining had progressed south to the area under the North Open Cut, and north almost to the Ompompanoosuc River. A 3,000 ft long secondary ore zone was discovered west of the main orebody and mined via a 150 ft long crosscut. Secondary ore shoots in the zone west of the surface plant were mined from below via the 575 ft and 975 ft levels. By 1958, when the mine closed, underground mining extended to a point 1,600 ft north of the river, about 200 ft below the riverbed.

Mining was mechanized, using compressed air and electrically powered scrapers, loaders, locomotives, and ore cars. Mining followed two methods depending on configuration of the orebody. In sub-level stoping blocks of ore were mined in horizontal benches from the bottom up, supplying a constant flow of freshly broken ore. In shrinkage stoping mining progressed upward leaving broken ore to oxidize, which interfered with the milling process. Ventilation was provided by a fan in the 1948 shaft, and additional vent pipes and an air shaft were sunk near the river.





Translucent Block Diagram

Topography is approximate
No scale
Some buildings and surface details removed for clarity
Flow of ore
North

Consult the Appendix for the Narrative Report for source credits for all 4 drawings

DELINEATED BY: DENNIS O'BRIEN, ILLUSTRATOR, MYSTIC, CT 12/2003 DATA COMPILED BY MATT KIERSTEAD, INDUSTRIAL HISTORIAN, PUBLIC ARCHAEOLOGY LABORATORY, PAWTUCKET, RI

ELIZABETH MINE RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

VERMONT COPPER COMPANY INC. ELIZABETH MINE 1942 - 1958
MINE ROAD
SOUTH STRAFFORD STRAFFORD/THETFORD TOWNSHIPS ORANGE COUNTY VERMONT

SHEET 3 OF 4

HISTORIC AMERICAN ENGINEERING RECORD

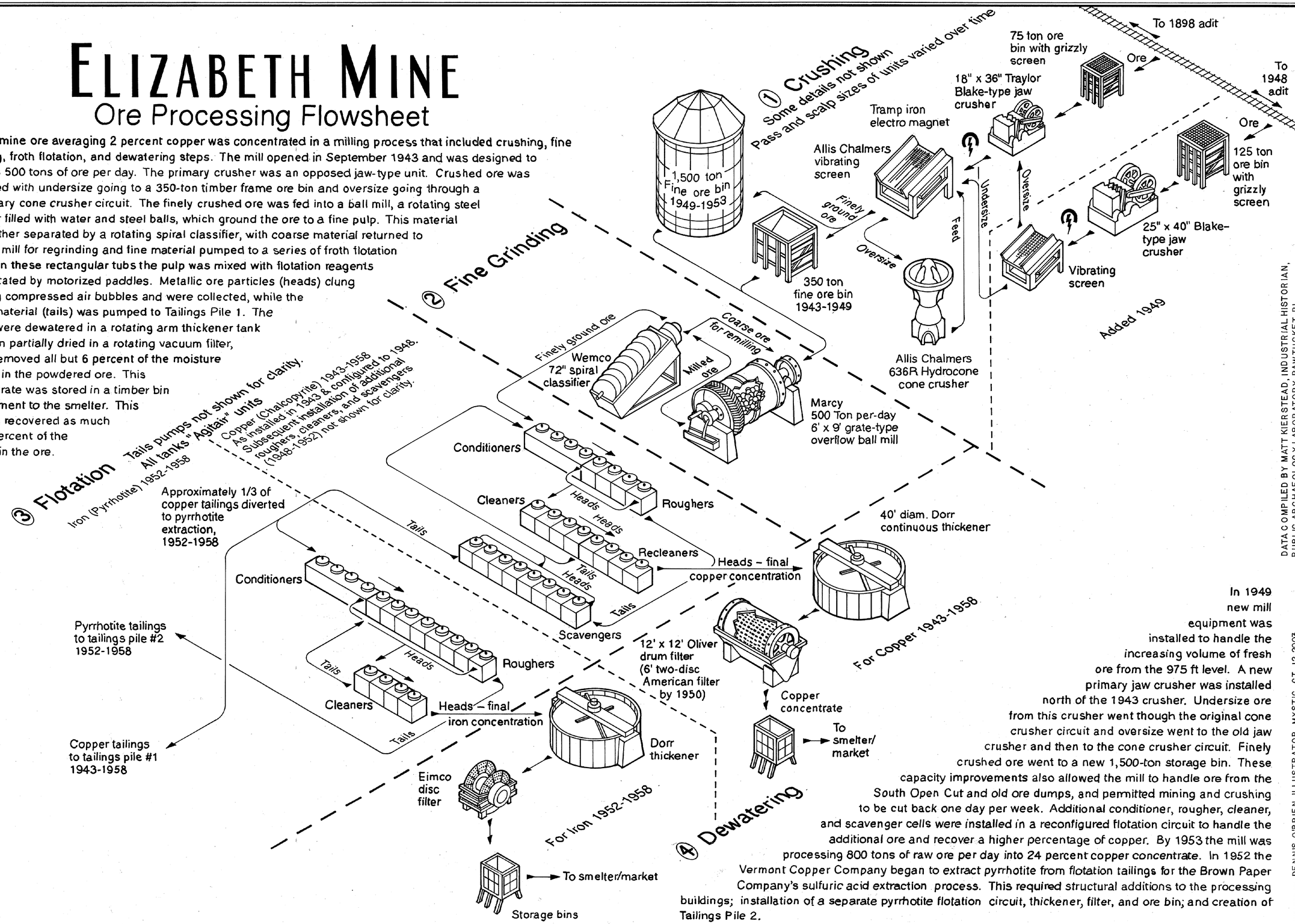
LIBRARY OF CONGRESS
PRINTS AND PHOTOGRAPHS DIVISION

IF REPRODUCED, PLEASE CREDIT: HISTORIC AMERICAN ENGINEERING RECORD, NATIONAL PARK SERVICE, NAME OF DELINEATOR, DATE OF THE DRAWING

ELIZABETH MINE

Ore Processing Flowsheet

Run-of-mine ore averaging 2 percent copper was concentrated in a milling process that included crushing, fine grinding, froth flotation, and dewatering steps. The mill opened in September 1943 and was designed to process 500 tons of ore per day. The primary crusher was an opposed jaw-type unit. Crushed ore was screened with undersize going to a 350-ton timber frame ore bin and oversize going through a secondary cone crusher circuit. The finely crushed ore was fed into a ball mill, a rotating steel cylinder filled with water and steel balls, which ground the ore to a fine pulp. This material was further separated by a rotating spiral classifier, with coarse material returned to the ball mill for regrinding and fine material pumped to a series of froth flotation tanks. In these rectangular tubs the pulp was mixed with flotation reagents and agitated by motorized paddles. Metallic ore particles (heads) clung to rising compressed air bubbles and were collected, while the waste material (tails) was pumped to Tailings Pile 1. The heads were dewatered in a rotating arm thickener tank and then partially dried in a rotating vacuum filter, which removed all but 6 percent of the moisture content in the powdered ore. This concentrate was stored in a timber bin for shipment to the smelter. This process recovered as much as 95 percent of the copper in the ore.



In 1949 new mill equipment was installed to handle the increasing volume of fresh ore from the 975 ft level. A new primary jaw crusher was installed north of the 1943 crusher. Undersize ore from this crusher went though the original cone crusher circuit and oversize went to the old jaw crusher and then to the cone crusher circuit. Finely crushed ore went to a new 1,500-ton storage bin. These capacity improvements also allowed the mill to handle ore from the South Open Cut and old ore dumps, and permitted mining and crushing to be cut back one day per week. Additional conditioner, rougher, cleaner, and scavenger cells were installed in a reconfigured flotation circuit to handle the additional ore and recover a higher percentage of copper. By 1953 the mill was processing 800 tons of raw ore per day into 24 percent copper concentrate. In 1952 the Vermont Copper Company began to extract pyrrhotite from flotation tailings for the Brown Paper Company's sulfuric acid extraction process. This required structural additions to the processing buildings; installation of a separate pyrrhotite flotation circuit, thickener, filter, and ore bin; and creation of Tailings Pile 2.

Consult the Appendix for the Narrative Report for source credits for all 4 drawings

DELINEATED BY: DENNIS O'BRIEN, ILLUSTRATOR, MYSTIC, CT 12 2003

ELIZABETH MINE RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

DATA COMPILED BY MATT KIERSTEAD, INDUSTRIAL HISTORIAN, PUBLIC ARCHAEOLOGY LABORATORY, PAWTUCKET, RI

VERMONT COPPER COMPANY, INC. MINE ROAD, ELIZABETH MINE 1942 – 1958
SOUTH STRAFFORD STRAFFORD THETFORD TOWNSHIPS ORANGE COUNTY VERMONT

HISTORIC AMERICAN ENGINEERING RECORD

SHEET 4 OF 4

IF REPRODUCED, PLEASE CREDIT: HISTORIC AMERICAN ENGINEERING RECORD, NATIONAL PARK SERVICE, NAME OF DELINEATOR, DATE OF THE DRAWING

Attachment 1

Media Sampling Locations

DRAFT

UPPER WEST BRANCH OF THE OMPOMPANOSUC RIVER

ARTESIAN VENT

MINE POOL ACCESS & FURNACE FLATS

SARGENT BROOK

SMELTER AREA

MILE 0

CONFLUENCE COPPERAS BROOK AND WBOR

TP-1 AND LOWER COPPERAS BROOK

COPPERAS BROOK

MILE 1

SOIL SAMPLE LOCATIONS LS-103 & LS-235 ARE DOWNSTREAM. REFER TO INSET MAPS BELOW.

NORTH OPEN CUT

T2 AND UPPER COPPERAS BROOK

AROUND TP-1, TP-2 AND TP-3

MILE 0

SOUTH OPEN CUT

LORD BROOK

MILE 1

SOUTH MINE

SOUTH MINE

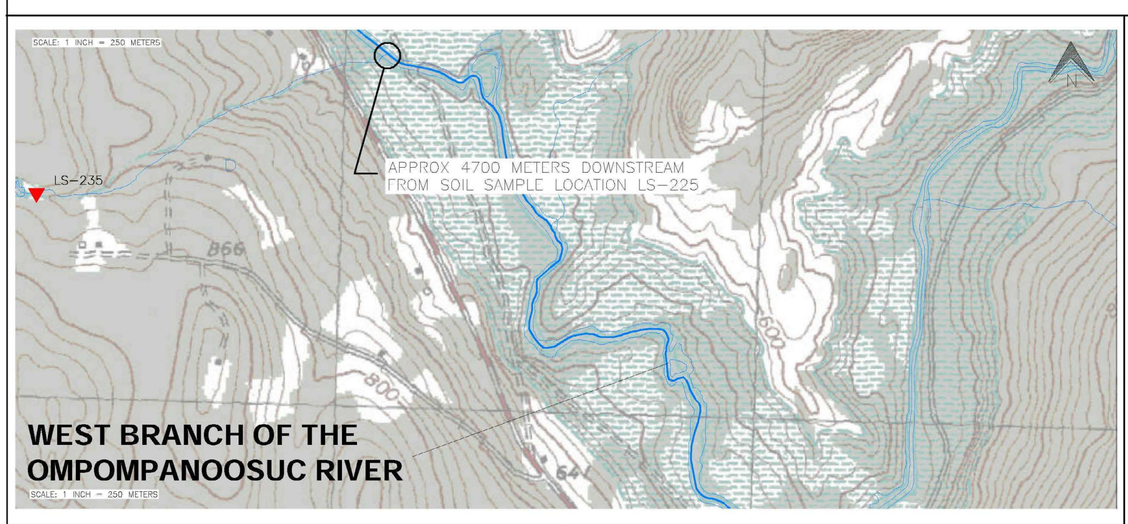
LEGEND

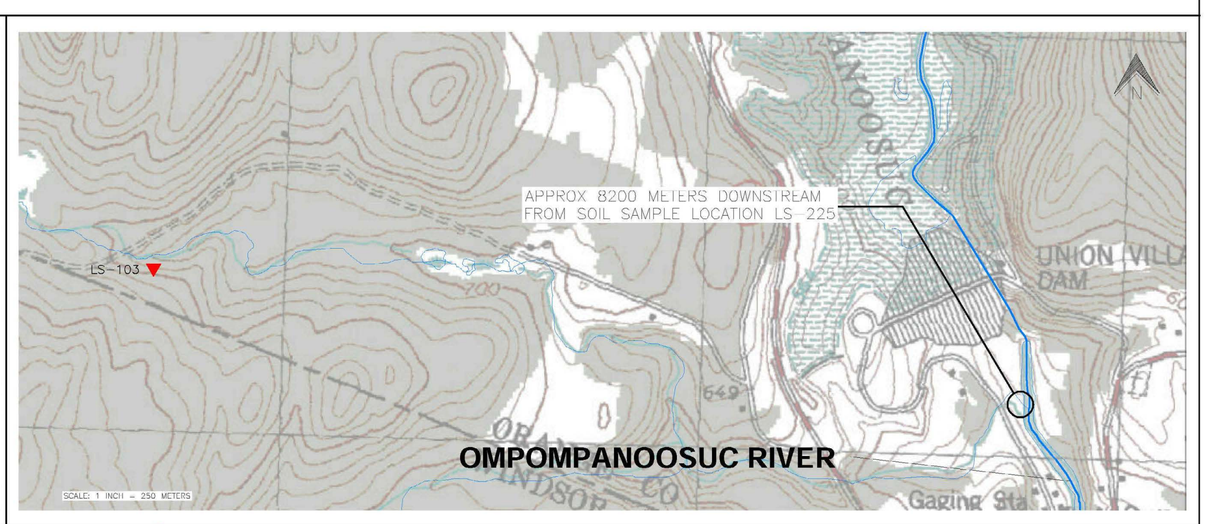
- TB-03 TEST BORING WITH PIEZOMETER
- TB-04 INSTALLED TEST BORING SURFICIAL
- SL-402 SOIL SAMPLE LOCATION LATERAL SOIL
- LS-224 SAMPLE TRANSECT LOCATION TAILING
- TS-61 SOIL SAMPLE LOCATION SURFICIAL
- LOC-02_SO SOIL SAMPLE LOCATION
- SOURCE AREA
- BORDERING TERRESTRIAL AND WETLAND HABITAT
- RIPARIAN CORRIDOR

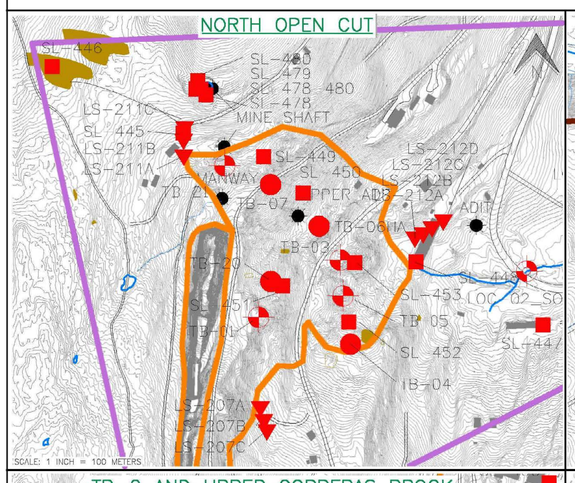
Source:
USGS 7.5-minute topographic quadrangles of South Strafford,VT (1981); Sharon, VT (1981); Chelsea, VT (1981); Hanover, NH (1988); and Lyme, NH (1983) obtained from Vermont Center for Geographic Information, Inc. Waterbury, VT in digital format (.tiff files) projected in the Vermont State Plane coordinate system (NAD83) from Digital Raster Graphic image files.
Historic site features and 1-meter interval contour base map obtained from Public Archaeology Lab (PAL), Pawtucket, Rhode Island, Report No. 1237.03, September 2002.
Water course data obtained from the Vermont Center for Geographic Information, Inc. Waterbury, VT and PAL, Report No. 1237.03, September 2002, modified based on site reconnaissance.

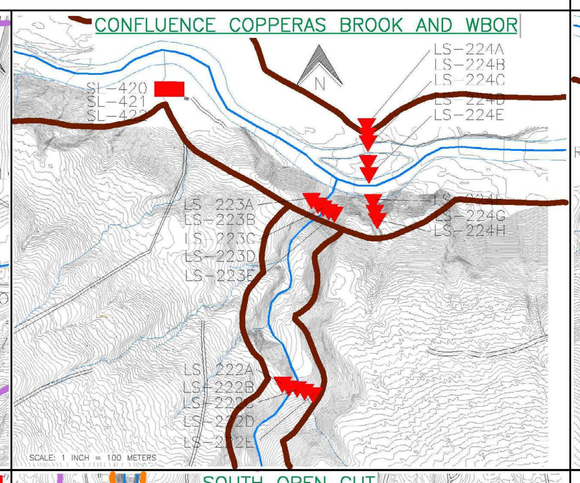
SCALE: 1 INCH = 250 METERS

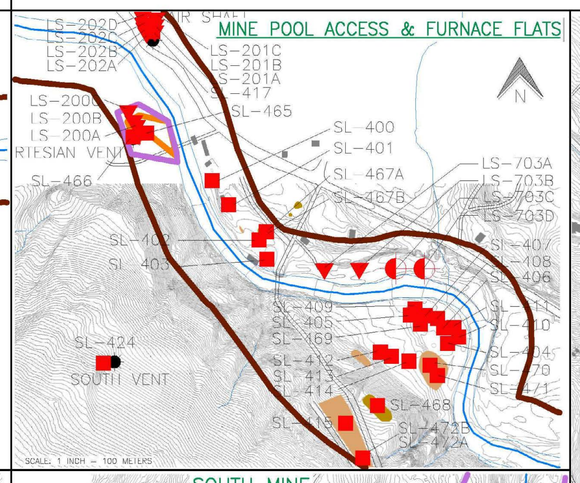
INSET MAPS

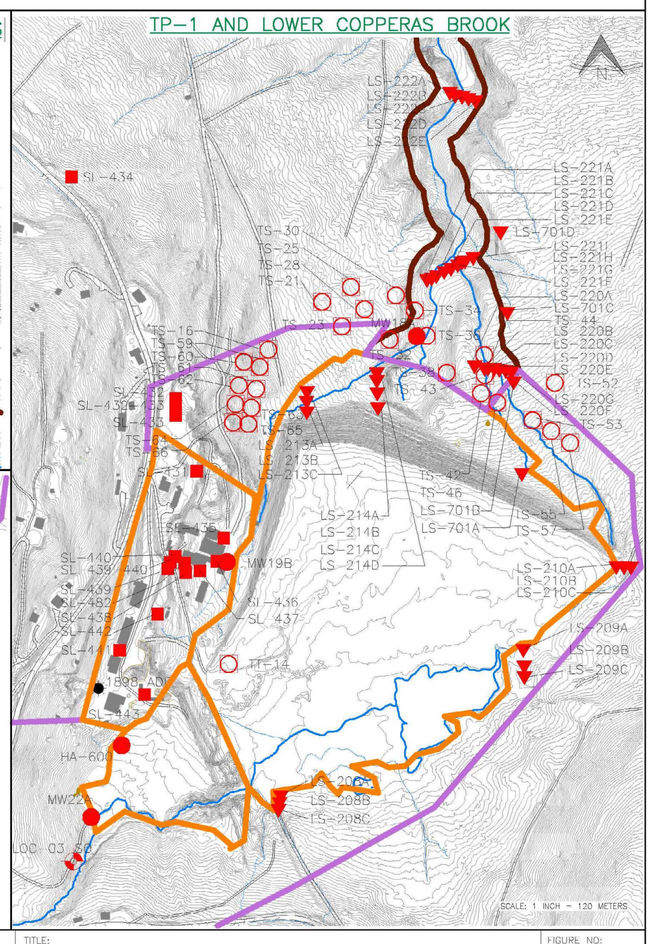


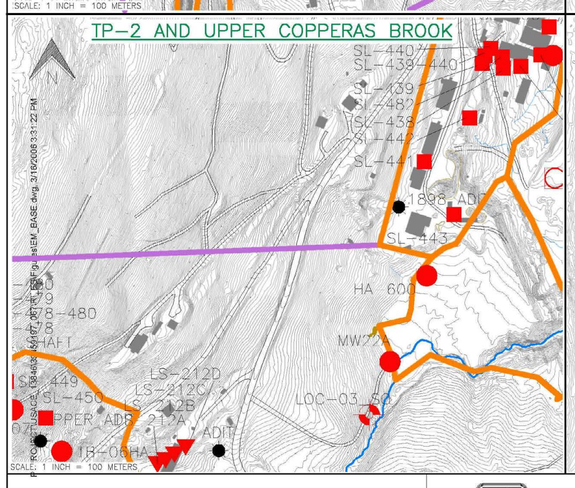


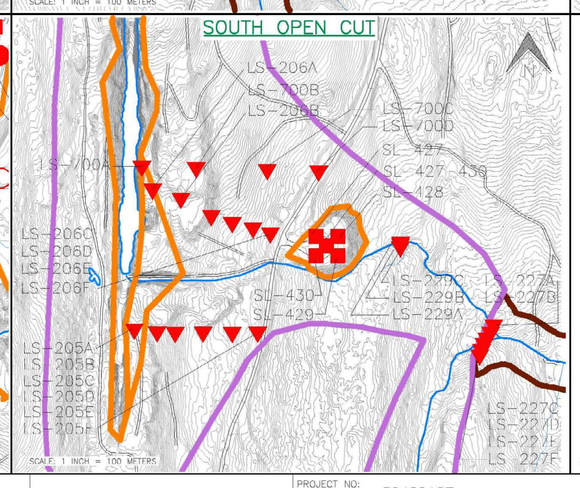


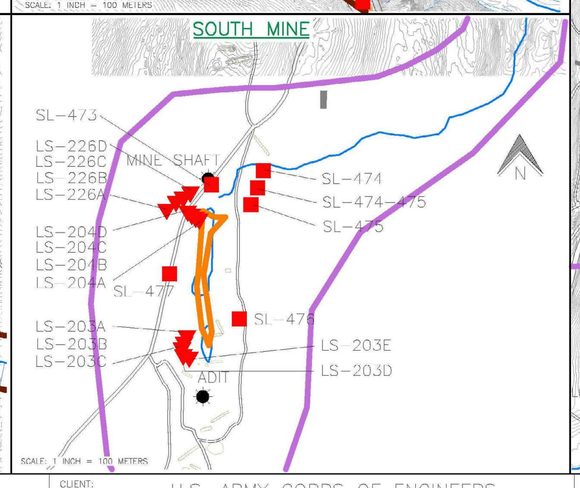












URS Corporation
477 Congress Street, 9th Floor
Portland, ME 04101-3453
Tel: 207.879.7686
Fax: 207.879.7685

U.S. Army Corps Of Engineers New England District

0 200 400
SCALE in METERS

PROJECT NO:	39459197		
DESIGN:	FS	SCALE:	1"=200m
APPROVED:	JCC	DATE:	M ARCH 2006
DRAWN:	FS	FILE NO:	EM_BASE

CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJECT: ELIZABETH MINE
BASELINE ECOLOGICAL RISK ASSESSMENT
STRAFFORD, VERMONT

TITLE: TERRESTRIAL AND WETLAND EXPSOURE UNITS AND SOIL SAMPLE LOCATIONS

FIGURE NO: 3

WEST BRANCH OF THE OMPOMPANOOSUC RIVER SARGENT BROOK TO COPPERAS BROOK

LOCATION OF LOC-37

MINE POOL ACCESS

WEST BRANCH OF THE OMPOMPANOOSUC RIVER DOWNSTREAM OF MIXING ZONE

MILE 0

MIXING ZONE

MILE 1

COPPERAS BROOK

CONFLUENCE COPPERAS BROOK AND WBOR

SARGENT BROOK

TP-1 AND LOWER COPPERAS BROOK

TP-2 AND UPPER COPPERAS BROOK

UPPER COPPERAS BROOK

MILE 0

SOUTH OPEN CUT

SOUTH MINE

MILE 1

LORD BROOK

MILE 2

MILE 2

MILE 3

SOUTH MINE DRAINAGE

MILE 4

MILE 5

OMPOMPANOOSUC RIVER

MILE 6

MILE 7

MILE 8

CONNECTICUT RIVER

LEGEND

LOC-13 SD-418 SEDIMENT SAMPLE LOCATION

SOURCE AREA

AQUATIC HABITAT

DRAFT

Source:
USGS 7.5-minute topographic quadrangles of South Strafford,VT (1981); Sharon, VT (1981); Chelsea, VT (1981); Hanover, NH (1988); and Lyme, NH (1983) obtained from Vermont Center for Geographic Information, Inc. Waterbury, VT in digital format (.tiff files) projected in the Vermont State Plane coordinate system (NAD83) from Digital Raster Graphic image files.
Historic site features and 1-meter interval contour base map obtained from Public Archaeology Lab (PAL), Pawtucket, Rhode Island, Report No. 1237.03, September 2002.
Water course data obtained from the Vermont Center for Geographic Information, Inc. Waterbury, VT and PAL, Report No. 1237.03, September 2002, modified based on site reconaissance.

INSET MAPS

LOCATION OF LOC-37

CONFLUENCE COPPERAS BROOK AND WBOR

MINE POOL ACCESS

AIR SHAFT

ARTESIAN VENT

SOUTH VENT

TP-1 AND LOWER COPPERAS BROOK

TP-2 AND UPPER COPPERAS BROOK

SOUTH OPEN CUT

SOUTH MINE

MINE SHAFT

ADIT

SCALE: 1 INCH = 100 METERS

URS
URS Corporation
477 Congress Street, 9th Floor
Portland, ME 04101-3453
Tel: 207.879.7686
Fax: 207.879.7685

U.S. Army Corps Of Engineers New England District

0 500 1000
SCALE in METERS

PROJECT NO:	39459197
DESIGN:	FS
SCALE:	1"=500m
APPROVED:	JCC
DATE:	MARCH 2005
DRAWN:	FS
FILE NO:	FM_BASE

CLIENT: U.S. ARMY CORPS OF ENGINEERS

PROJECT: ELIZABETH MINE
BASELINE ECOLOGICAL RISK ASSESSMENT
STRAFFORD, VERMONT

TITLE: AQUATIC EXPOSURE UNITS AND SEDIMENT SAMPLE LOCATIONS

FIGURE NO: 2

DRAFT

WEST BRANCH OF THE OMPOMPANOOSUC RIVER UPSTREAM OF COPPERAS BROOK

MINE POOL ACCESS & FURNACE FLATS

WEST BRANCH OF THE OMPOMPANOOSUC RIVER DOWNSTREAM OF MIXING ZONE

MIXING ZONE

MILE 0

MILE 1

CONFLUENCE LORD BROOK AND WBOR

COPPERAS BROOK

CONFLUENCE COPPERAS BROOK AND WBOR

SARGENT BROOK

TP-1 AND LOWER COPPERAS BROOK

TP-2 AND UPPER COPPERAS BROOK

UPPER COPPERAS BROOK

MILE 2

MILE 3

SOUTH OPEN CUT

LORD BROOK

TRIBUTARIES TO LORD BROOK

MILE 4

OMPOMPANOOSUC RIVER

UNION VILLAGE DAM

MILE 5

MILE 6

MILE 7

MILE 8

CONNECTICUT RIVER

LEGEND

SURFACE WATER SAMPLE LOCATION

SOURCE AREA

Source:
USGS 7.5-minute topographic quadrangles of South Strafford,VT (1981); Sharon, VT (1981); Chelsea, VT (1981); Hanover, NH (1988); and Lyme, NH (1983) obtained from Vermont Center for Geographic Information, Inc. Waterbury, VT in digital format (.tiff files) projected in the Vermont State Plane coordinate system (NAD83) from Digital Raster Graphic image files.
Historic site features and 1-meter interval contour base map obtained from Public Archaeology Lab (PAL), Pawtucket, Rhode Island, Report No. 1237.03, September 2002.
Water course data obtained from the Vermont Center for Geographic Information, Inc. Waterbury, VT and PAL, Report No. 1237.03, September 2002, modified based on site reconaissance.

INSET MAPS

CONFLUENCE LORD BROOK AND WBOR

CONFLUENCE COPPERAS BROOK AND WBOR

SOUTH OPEN CUT

TP-1 AND LOWER COPPERAS BROOK

TP-2 AND UPPER COPPERAS BROOK

MINE POOL ACCESS & FURNACE FLATS

SOUTH MINE

URS Corporation, 477 Congress Street, 9th Floor, Portland, ME 04101-3453, Tel: 207.879.7686, Fax: 207.879.7685	U.S. Army Corps Of Engineers, New England District	0 550 1100 SCALE in METERS	PROJECT NO: 39459197
DESIGN: FS	SCALE: 1"=550m	CLIENT: U.S. ARMY CORPS OF ENGINEERS	TITLE: AQUATIC EXPOSURE UNITS AND SURFACE WATER SAMPLE LOCATIONS
APPROVED: JCC	DATE: MARCH 2006	PROJECT: ELIZABETH MINE BASELINE ECOLOGICAL RISK ASSESSMENT STRAFFORD, VERMONT	FIGURE NO: 1
DRAWN: FS	FILE NO: EM_BASE		