

History of the Christmas Mine, Gila County Arizona

David F. Briggs

March 2021

CONTRIBUTED REPORT CR-21-A
Arizona Geological Survey

azgs.arizona.edu | repository.azgs.az.gov



UA Science

Arizona Geological Survey

Philip A. Pearthree, Director

Manuscript approved for publication in March 2021

Printed by the Arizona Geological Survey

All rights reserved

For an electronic copy of this publication: www.repository.azgs.az.gov

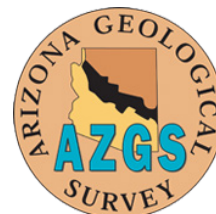
For information on the mission, objectives or geologic products of the Arizona Geological Survey visit azgs.arizona.edu

This publication was prepared by a department of the University of Arizona. The University of Arizona, or any department thereof, or any of their employees, makes no warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed in this report. Any use of trade, product, or firm names in this publication is for descriptive purposes only and does not imply endorsement by the University of Arizona

Arizona Geological Survey Contributed Report series provides non-AZGS authors with a forum for publishing documents concerning Arizona geology. While review comments may have been incorporated, this document does not necessarily conform to AZGS technical, editorial, or policy standards. The Arizona Geological Survey issues no warranty, expressed or implied, regarding the suitability of this product for a particular use. Moreover, the Arizona Geological Survey shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product. The author(s) is solely responsible for the data and ideas expressed herein.

Recommended Citation: Briggs, D.F., 2021, History of the Christmas Mine, Gila County, Arizona. Arizona Geological Survey Contributed Report CR-21-A, 45 p.

Cover: Oblique aerial view of the Christmas Mine, looking southwest on 3 May 2019 (image from Google Earth).





Christmas Mine, looking west up Copper Canyon, circa 2010
(photo provided by Ken Krahulec)

TABLE OF CONTENTS

1	INTRODUCTION	1
1.1	Advancements in our Knowledge of Porphyry Coppers	2
1.2	Christmas Porphyry Copper	3
2	REGIONAL GEOLOGY AND SETTING	3
2.1	Structural Setting.....	6
2.2	Alteration and Mineralization	7
3	MINING HISTORY OF CHRISTMAS (1880 TO PRESENT).....	12
3.1	Early History (1880-1902)	12
3.2	Saddle Mountain Mining Company (1902-1909).....	13
3.3	Gila Copper Sulphide Company (1909-1925)	18
3.4	Christmas Copper Company (1925-1938)	22
3.5	Sam Knight Mining Lease, Inc. (1939-1953)	24
3.6	Riviera Mines Company (1953-1954).....	26
3.7	Inspiration Consolidated Copper Company (1954-1988)	27
3.7.1	Early Development (1954-1962).....	28
3.7.2	Underground Operations (1962-1966).....	30
3.7.3	Exploration Success	32
3.7.4	Open Pit Operations (1966-1981).....	33
3.8	Recent History (1988 to Present).....	36
4	ACKNOWLEDGMENTS	37
5	REFERENCES CITED	37

List of Tables

Table 1. Reported production from the Christmas Mine, 1905-1981 (modified from U.S. Bureau of Mines data)	35
---	----

LIST OF FIGURES

Figure 1. Topographic relief map showing location of the Christmas Mine	1
Figure 2. Stratigraphic section for the Christmas area (modified from Eastlick, 1968; and Willden, 1964).....	4
Figure 3. Geologic map of the Christmas Mine (modified from Koski, 1979). Note: Much of the Christmas Stock is concealed beneath a thin veneer of Quaternary talus or waste dumps	5
Figure 4. West-east geologic cross section (8500 N, view to the north) at Christmas showing the distribution of copper mineralization (modified from (White and Thoman, 2014)	7
Figure 5. Sulfide mineral zoning in igneous rocks and skarn ores at Christmas (modified from Peterson and Swanson, 1956; and Koski and Cook, 1982)	8
Figure 6. Magnetite-garnet-chalcopyrite-sphalerite skarn in the Naco Limestone from east of the Joker Fault (photo from White and Thoman, 2014)	10
Figure 7. Oxide copper mineralization hosted by the Christmas Stock between the Christmas and Joker faults (photo from White and Thoman, 2014).....	11
Figure 8. Map showing portion of the San Carlos Indian Reservation, which was returned to the public domain on December 22, 1902 (modified from Welch, 2017)	13
Figure 9. George Chittenden (1849-1939) served as general manager of the Saddle Mountain Mining Company from 1902-1907 (photo from Arizona Historical Society)	14
Figure 10. Early surface workings at Christmas, circa 1900s (photo by Arizona Geological Survey)	14
Figure 11. Teamsters hauling coke from the Phoenix and Eastern rail head at Winkelman to Saddle Mountain Mining's Christmas Smelter, circa 1906 (photo from Arizona Geological Survey).....	15
Figure 12. Saddle Mountain Mining Company's Christmas Smelter, circa 1906 (photo from the Arizona Geological Survey)	16

Figure 13. Christmas Mine infrastructure from 1905-1921. Underground workings on the 300 level and stopes above the 800 level have been projected to the surface. Note: All of the mine workings are in the footwall of the Christmas-Joker Fault System along the southern and western contacts of the Christmas Stock. (modified from Peterson and Swanson, 1956; and Koski, 1979)	17
Figure 14. Topographic map showing Southern Pacific Railroad and the Arizona Eastern Railroad, which completed its spur to Christmas in June 1911 (Irvin, 1987)	18
Figure 15. No. 3 Shaft and hoist house at Christmas, circa 1916 (photo from Anonymous, 1916)	19
Figure 16. Bleichert aerial tram system at Christmas, circa 1916 (photo from Anonymous, 1916)	20
Figure 17. Christmas town site during the early 1900s consisted of a mixture of frame and temporary structures. These temporary structures (known as tent tops) had canvas roofs and wooden sides with dirt or wood floors. Much of this housing could be purchased by the miners as prefabricated and easily assembled kits. By World War I, many of these temporary structures were replaced by frame structures (photo from the Arizona Geological Survey)	21
Figure 18. Christmas Mine infrastructure from 1929-1954. Underground workings on the 400 level and stopes above the 800 level have been projected to the surface. Note: All of the mine workings are in the footwall of the Christmas-Joker Fault System along the southern and western contacts of the Christmas Stock. (modified from Peterson and Swanson, 1956; and Koski, 1979)	23
Figure 19. McDonald Shaft (also known as the No. 9 Shaft), circa 1960s (photo from the Arizona Geological Survey)	29
Figure 20. Double-drum hoist and steam turbine in hoist house, circa 1960s (photo from Arizona Geological Survey)	30
Figure 21. Christmas Mine infrastructure from 1962-1981. The 1600 Level workings have been projected to the surface. Note: The open pit and underground mine occur in the footwall of the Christmas-Joker Fault System along the southern and western contacts of the Christmas Stock. (modified from Koski, 1979)	31
Figure 22. Distribution of porphyry copper mineralization at Christmas projected to the surface. Disseminated and stockwork mineralization is hosted by the Christmas Stock and Williamson Canyon Volcanics in the eastern hanging wall of the	

Christmas-Joker Fault System. Much of the Christmas Stock in the footwall of the Christmas Fault is located in the low-grade core of the system with high-grade copper-bearing skarn distributed along its western and southern contacts (modified from Koski and Cook, 1982)	32
---	----

1 INTRODUCTION

The Christmas copper deposit is located in southern-most Gila County, Arizona approximately 70 miles north of Tucson and 100 miles southeast of Phoenix (Figure 1). Situated in the Dripping Spring Mountains, it is about 1.7 miles west of the Gila River, approximately 7 miles north of its confluence with the San Pedro River near Winkelman.

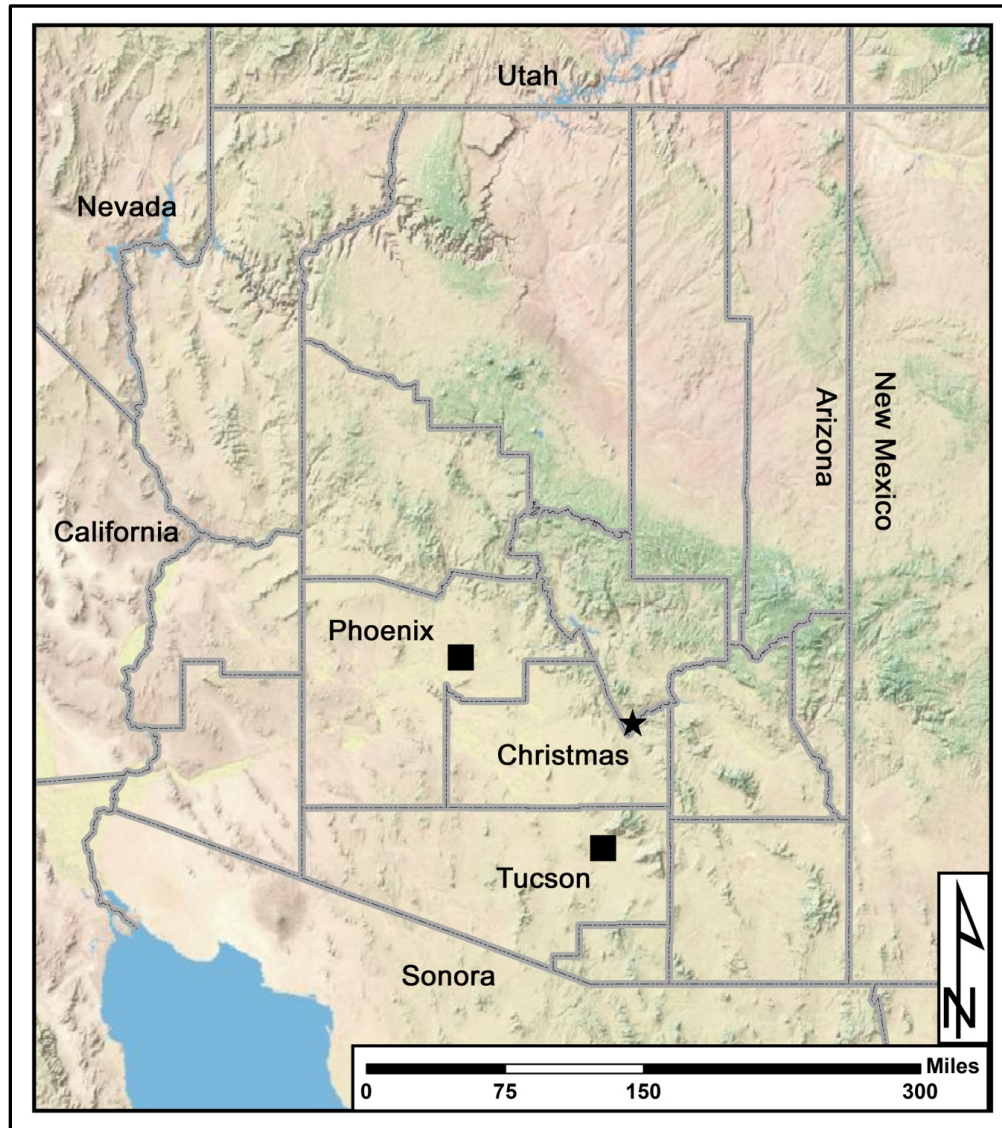


Figure 1. Topographic relief map showing location of the Christmas Mine

Although the mining history of Christmas was similar to its larger cousins (i.e. Bisbee, and Morenci), its development was slow and sporadic due to its smaller size and remote location. The presence of copper at Christmas has been known since 1880, but early development was temporarily halted in 1884, when a government survey revealed it was located within the San Carlos Indian Reservation. Although limited copper

production was finally achieved in August 1905, this effort was short-lived; suffering from poor management, high cost of supplies, and a lack of a reliable source of coke to fuel its smelter (Burns, 1919).

By the beginning of World War I, many of the challenges that hampered operations at Christmas had been resolved with the completion of a rail spur to Christmas in June 1911, and the commissioning of ASARCO's Hayden Smelter in April 1912 (Heikes, 1913). With ASARCO's financial and technical assistance, mining operations at Christmas resumed in February 1916 (Burns, 1919).

Over the next four decades, mining activities at Christmas ebbed and flowed depending on the copper price, but generally benefited from the superior metallurgical quality of the high-lime content of its ores that found a ready market at ASARCO's nearby Hayden Smelter (Schmitt, 1940).

During the early 1960s, operations by the Inspiration Consolidated Copper Company were less successful, initially encountering unforeseen ground support problems that eventually forced them to suspend underground mining operations in September 1966 (Larson and Henkes, 1967a). Efforts to resume production using open pit mining methods met additional logistical and metallurgical challenges that were only partially resolved before a collapse in the price of copper resulted in the suspension of all mining activities on January 2, 1982 (Burgin, 1984).

From 1905 through 1981, approximately 25.8 million tons of ore from the Christmas Mine yielded approximately 362.9 million lbs. of copper, 55,000 ounces of gold, and 2.15 million ounces of silver (Table 1).

1.1 Advancements in our Knowledge of Porphyry Coppers

A comprehensive review by Titley (1997) documents the evolution of our understanding of porphyry copper systems. These deposits were popularly known as "porphyry coppers" by the mining community as early as 1909 (Anonymous, 1909). The first use of the term "porphyry copper" in scientific literature occurred in the first edition of "Principles of Economic Geology" by Emmons (1918). Prior to that time and for many years thereafter, they were simply referred to as "disseminated copper ores" with most of the attention focused on the oxidization and enrichment of the primary sulfide mineralization. Although their spatial relationship with intermediate to felsic porphyritic intrusions had been recognized very early, the significance of a genetic relationship remained unclear. It was not until 1950 that A. M. Bateman (1950) assigned porphyry coppers to a genetic category in "Economic Mineral Deposits".

After much research on many aspects of these hydrothermal systems, a conceptual model for porphyry copper systems was published by J. David Lowell and John Guilbert in 1970 (Lowell and Guilbert, 1970). Refined versions of this simple ore deposit model continue to be useful in recognizing and evaluating the economic potential of these large mineral systems today (Seedorff et. al., 2005; Sinclair, 2007; Seedorff et. al., 2008; Berger et. al., 2008; and John et. al., 2010).

1.2 Christmas Porphyry Copper

Ransome (1919) reported as early as 1919 that the copper ores at Christmas appeared to be genetically related to the Christmas Stock. Consequently, this deposit was classified in the scientific literature as a pyrosomatic or contact metamorphic deposit until the mid-1960s (Ross, 1925; Peterson and Swanson, 1956; Eastlick, 1957; and Willden, 1964). Eastlick (1968) and Perry (1968) initially noted its similarity with other known porphyry copper systems, based on the presence of disseminated and stockwork porphyry-style mineralization and alteration assemblages encountered in the hanging wall of the Christmas-Joker Fault System during the early 1960s. Evidence gathered through subsequent exploration drilling during the late 1960s and early 1970s firmly established its reclassification as a porphyry copper system (Koski, 1978; Koski, 1979; and Einaudi, 1982).

2 REGIONAL GEOLOGY AND SETTING

Situated in the southeastern portion of the Dripping Spring Mountains, the stratigraphic section at Christmas includes the Early Proterozoic Pinal Schist, Middle Proterozoic Apache Group (Dripping Spring Quartzite and Mescal Limestone) and Troy Quartzite, Cambrian Abrigo Formation, Devonian Martin Formation, Mississippian Escabrosa Limestone, and the Pennsylvanian Naco Limestone. A description of the stratigraphic section is shown in Figure 2. An extensive complex of Middle Proterozoic diabase dikes and sills (U-Pb age – $1,120 \pm 10$ Ma) cut the Apache Group and Pinal Schist at Christmas (Wrucke, 1989).

With the exception of the Middle Proterozoic quartzites, most of the sedimentary sequence at Christmas consists of marine limestone, dolomite and shale. In the vicinity of the mine, only the Pennsylvanian Naco Limestone crops out at the surface (Figure 3). Exposures of Escabrosa Limestone and Martin Formation occur within underground workings, while knowledge of the older units is derived from samples obtained by deep diamond drilling programs (Tainter, 1948; and White and Thoman, 2014).

Age	Formation	Symbol	Lithologic Description
Recent	Alluvium		Gravel, sand and silt occurring along main washes and intermittent streams. (Thickness - less than 50 feet)
	Talus		Locally derived angular fragments of bedrock on steep hillsides and slope wash.
Middle Miocene to Pliocene	Gila Conglomerate		Coarse conglomeratic detritus largely derived from local sources with interbedded layers of sand and silt. Outcrops light gray to light brown, moderately well consolidated to friable; commonly cemented by silica or carbonate. Locally interbedded with basaltic lava flows. (Thickness - 900 feet)
Paleocene	Christmas Stock		Composite granodiorite stock with peripheral east-west striking porphyry dikes. Sub-divided into 1) an early veined quartz diorite, biotite granodiorite porphyry, and granodiorite and 2) a late unveined granodiorite porphyry and dacite porphyry. U-Pb zircon age - 65 ± 1.3 Ma.
Cretaceous	McDonald Stock		Hornblende rhyodacite porphyry stock and associated east-west trending dikes. Plagioclase, hornblende and biotite phenocrysts within an aphanitic groundmass of K-feldspar with lesser amounts of quartz and plagioclase. K-Ar age - 69.8 ± 2.1 Ma.
	Williamson Canyon Volcanics		Monotonous westward thinning sequence of dark gray to greenish gray basaltic to andesitic flows, volcanic breccias, and pyroclastics with subordinate amounts of intercalated clastic sediments. K/Ar Age - 76.2 ± 2.3 Ma. (Thickness - 800 to 3,000 feet)
	Pinkard Formation		Only basal conglomerate (5 to 10 feet) is locally present near Christmas, but thickens eastward to more than 1,000 feet, where it consists of an interbedded sequence of mudstone, shale, sandstone, and conglomerate with coal beds.
Pennsylvanian	Naco Limestone		Thin to thick-bedded, light to dark gray, fossiliferous limestone with variable amounts of shale interbeds. Locally contains chert nodules. (Thickness - 1,000 feet)
Mississippian	Escabrosa Limestone		Massive light gray, fine to coarse-grained crystalline limestone, locally thin-bedded and cherty in upper part (Thickness - 550 feet)
Devonian	Martin Formation		Basal member - O'Carroll bed - thin-bedded dolomite with interbedded limestone, shale and shaley limestone (Thickness - 30 feet). Middle member - massive light gray, fine-grained limestone with quartzite beds in upper part (Thickness - 170 feet). Upper member - Thin-bedded, shaly limestone with argillaceous and calcareous shale (Thickness - 65 feet).
Cambrian	Abrigo Formation		Basal conglomerate which is overlain by a granular quartzite with thin shale partings that grades upward into a calcareous and argillaceous quartzite with thin shale and limestone interbeds. (Thickness - 500 feet)
Middle Proterozoic	Diabase		Dark gray or dark greenish-gray, aphanitic to coarse-grained diabase, occurs as dikes and sills. K-Ar age - 1,050 to 1,068 Ma.
	Troy Quartzite		Braided stream deposits represented by a basal conglomerate grading upward into a dark reddish-brown, pebbly sandstone and argillaceous sandstone. (Thickness - 900 feet)
	Apache Group	Basalt	Dark green to dark gray, vesicular and amygdaloidal basalt flow. (Thickness up to 50 to 75 feet)
		Mescal Limestone	Highly contorted, thinly laminated light reddish gray to gray sandy dolomite, medium-bedded gray, cherty limestone and white marble (Thickness - 200-250 feet)
		Dripping Spring Quartzite	Tidal flat and braided stream deposits represented by a basal quartz pebble conglomerate (5 to 10 feet) locally known as the Barnes Conglomerate, which is overlain by medium to thick-bedded, gray to tan quartzite (100 feet); interbedded reddish-brown to gray quartzite and red shale (150 feet); and an upper thin-bedded, feldspathic quartzite (75 feet).
		Pioneer Shale	Interbedded reddish brown shale and light yellowish-brown to green siltstone and sandy siltstone, which frequently contain numerous small oval greenish-gray spots. (Thickness - up to 180 feet)
		Scanlon Conglomerate	Well-rounded quartzite and quartz pebbles in an arkosic sand matrix. (Thickness - 5 to 10 feet)
Early Proterozoic	Pinal Schist		Turbidite sequence, now represented fine to coarse-grained, isoclinally folded, light to dark gray quartz-muscovite schist with variable amounts of chlorite.

Figure 2. Stratigraphic section for the Christmas area (modified from Eastlick, 1968; and Willden, 1964)

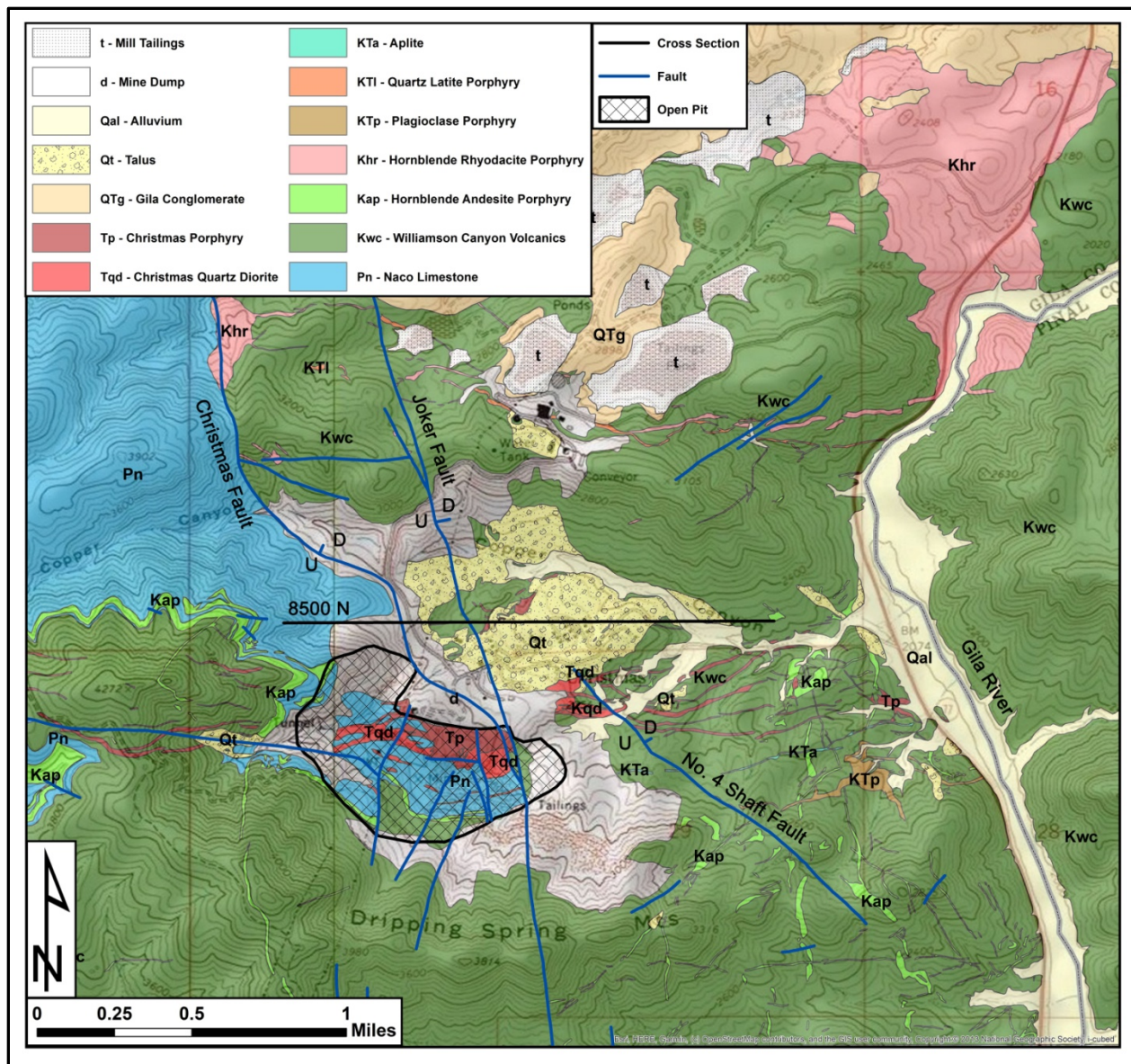


Figure 3. Geologic map of the Christmas Mine (modified from Koski, 1979). Note: Much of the Christmas Stock is concealed beneath a thin veneer of Quaternary talus or waste dumps

The Paleozoic section is locally overlain by a thin conglomeratic unit (i.e. Pinkard Formation), which is succeeded by a thick sequence of Late Cretaceous Williamson Canyon Volcanics (K/Ar Age – 76.2 ± 2.3 Ma) (Reynolds, et. al., 1986). This unit is characterized by a monotonous westward thinning sequence of dark gray to greenish gray, basaltic to andesitic flows, breccias, and fragmental pyroclastics with lesser amounts of interbedded, clastic sediments. Southeast of the Christmas Mine, the volcanic section has been cut by numerous hornblende andesite porphyry dikes, sills,

and irregular plug-like bodies that appear to represent in high level feeders for this extrusive sequence (Koski and Cook, 1982).

The Williamson Canyon Volcanics and older units are cut by the McDonald and Christmas stocks. Outcropping along Route 77, approximately 2.5 miles northeast of the mine site, the older, Late Cretaceous McDonald Stock (K-Ar age – 69.8 ± 2.1 Ma) is a hornblende rhyodacite porphyry (Reynolds, et. al., 1986). It is unmineralized and only exhibits weak propylitic alteration that is attributed to pervasive deuteritic processes (Koski and Cook, 1982).

Early Paleocene porphyry copper mineralization at Christmas is centered on a small, east-west elongated quartz diorite to granodiorite porphyry stock, which measures approximately 3,000 feet east-west and 1,500 feet north-south at its present level of erosion (Koski and Cook, 1982). An east-west trending porphyry dike swarm extends outward from the main stock, cutting Paleozoic sediments and volcanics west and east of the main intrusive body, respectively. Recent U-Pb zircon dating of the Christmas Stock yields an age of 65.0 ± 1.3 Ma (Seedorf et. al., 2019).

2.1 Structural Setting

The stratigraphic section at Christmas generally strikes east-west and dips gently to the south at 12 to 25 degrees (Koski and Cook, 1982). Three major northwest to north-northwest trending, post-mineral, normal faults at Christmas displaced the stratigraphic sequence and copper mineralization down to the east, juxtaposing different levels of the Christmas porphyry copper system during Late Oligocene to Middle Miocene time (Maher, 2008) (Figure 4).

From west to east, these faults include the Christmas Fault, Joker Fault, and the No. 4 Shaft Fault (also known as the Old Mill Fault). Displacement along these major structures is approximately 1,000 to 1,500 feet along the Christmas Fault, 1,500 to 2,000 feet along the Joker Fault, and 200 to 400 feet along the No. 4 Shaft Fault (Koski, 1979). The Christmas and Joker fault zones merge along the eastern side of the Christmas pit, forming a prominent zone of strongly shattered and broken rock (White and Thoman, 2014).

Lower levels of the Christmas porphyry system are located in the western footwall of the Christmas/Joker Fault System, where the Pennsylvanian Naco Limestone and lower levels of the Christmas Stock crop out at the surface (Figure 4). Much of the early copper production at Christmas was derived from high-grade ores hosted by favorable stratigraphic horizons in the Naco Limestone. Upper levels of the porphyry copper system occur in the eastern hanging wall of the Christmas-Joker Fault System, where

surface outcrops include a thick section of Williamson Canyon Volcanics and upper levels of the Christmas Stock (Koski and Cook, 1982).

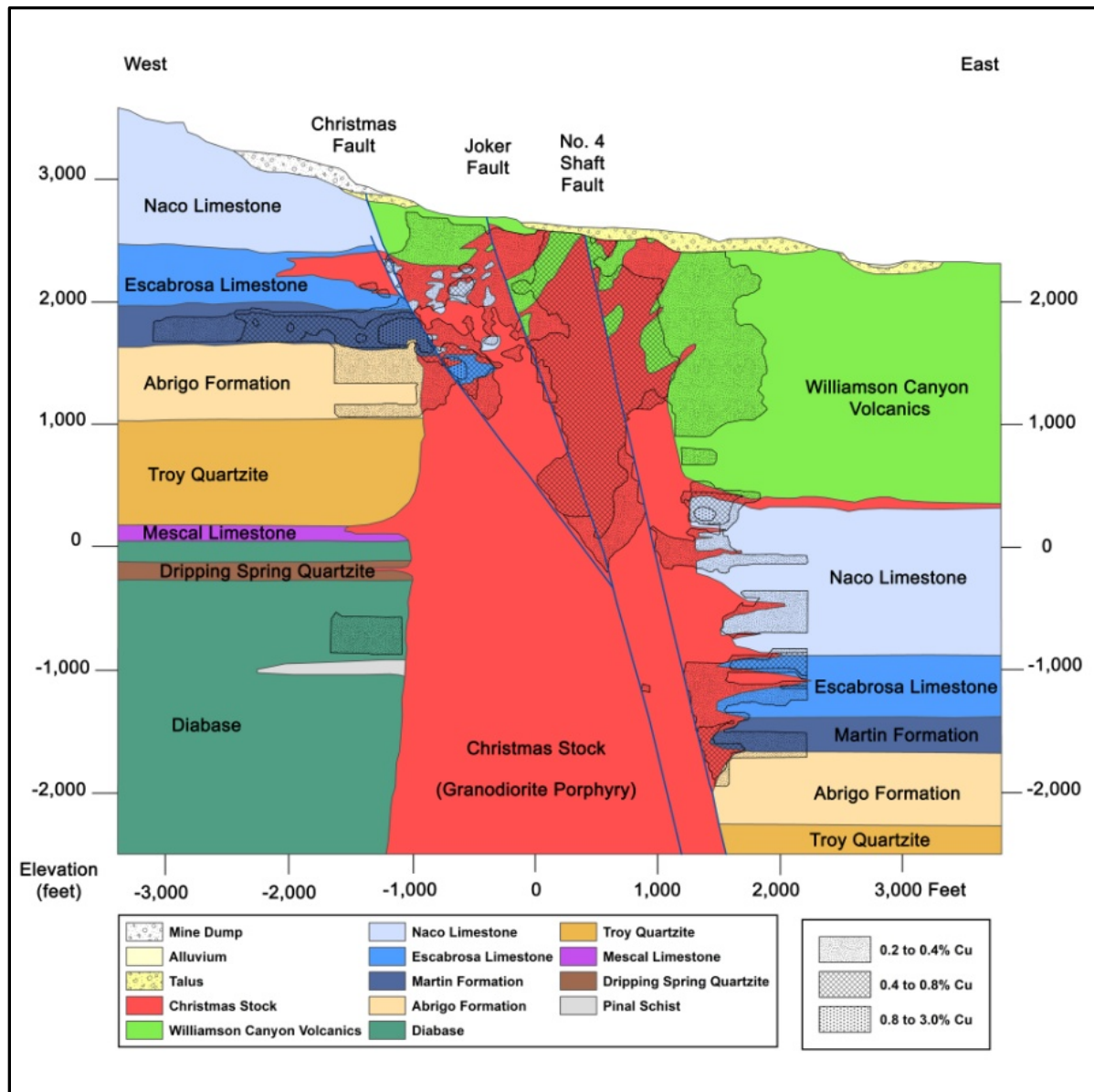


Figure 4. West-east geologic cross section (8500 N, view to the north) at Christmas showing the distribution of copper mineralization (modified from (White and Thoman, 2014))

2.2 Alteration and Mineralization

The small, compact porphyry copper system at Christmas is centered on the early Paleocene Christmas Stock. The deposit is generally upright, but may have been tilted as much as 15 to 20 degrees to the west-southwest (Einaudi, 1982; and Maher, 2008).

Upper levels of the stock cut mafic extrusive rocks of the Late Cretaceous Williamson Canyon Volcanics, where observed alteration assemblages are similar to other porphyry copper systems. However, its potassic and phyllic alteration zones are tightly confined around the central stock, while peripheral propylitic (actinolite-chlorite-epidote-calcite $\pm$ albite $\pm$ quartz) alteration is more widespread. While much the observed propylitic assemblage may have resulted from complex interaction between the mafic volcanics and meteoric and/or juvenile water circulating within the accumulating volcanic pile, later vein-related assemblages (i.e. epidote) with sulfides appear to be spatially related to the mineralized porphyry at Christmas (Koski and Cook, 1982).

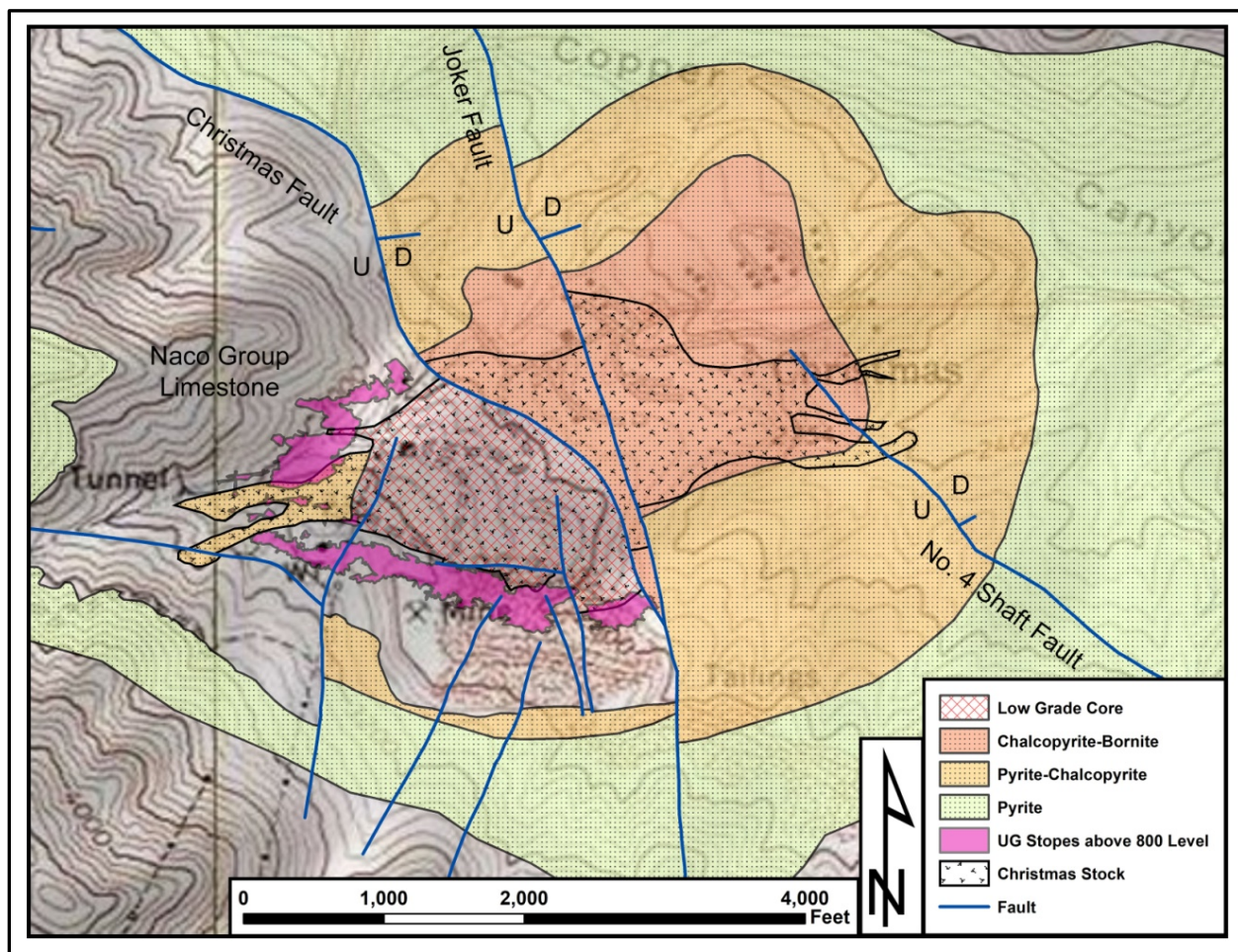


Figure 5. Sulfide mineral zoning in igneous rocks and skarn ores at Christmas (modified from Peterson and Swanson, 1956; and Koski and Cook, 1982)

A central zone of early potassic alteration is characterized by orthoclase-quartz-chalcopyrite-bornite-magnetite-molybdenite stockwork veining with partial biotitization of hornblende within the Christmas Stock. Quartz-magnetite-chalcopyrite $\pm$ bornite veinlets cut the adjacent mafic volcanics, which are pervasively altered to secondary biotite up to 650 feet from the intrusive-wall rock contact. Fracture-controlled phyllic alteration

(quartz-sericite-pyrite-chalcopyrite $\pm$ chlorite) was superimposed over the outer portion of the zone of early potassic alteration during the later stages of mineralization. Phyllic alteration produced the observed sulfide zoning pattern characterized by an inner chalcopyrite-bornite assemblage, intermediate pyrite-chalcopyrite assemblage and an outer pyrite assemblage, as shown in Figure 5. Much of the Christmas Stock in the western footwall of the Christmas Fault occurs within the low-grade core (<0.1% copper) of the porphyry copper system (Figure 5). The low-grade core is cut by orthoclase-quartz $\pm$ chalcopyrite veinlets and contains sparse disseminated chalcopyrite and bornite (Koski and Cook, 1982).

High-grade copper ores exploited by early underground and later open pit operations were developed as contact metamorphic deposits (i.e. skarn/replacement) hosted by Paleozoic carbonates along the western and southern margins of the Christmas Stock in the footwall of the Christmas Fault (Figure 5). A copper resource is also present in the same units at depth along the northern and eastern contacts of the Christmas Stock (White and Thoman, 2014) within the eastern, down-thrown hanging wall of the Joker and No. 4 Shaft Faults (Figure 4). Primary mineralization within these deposits is characterized by a pyrite-magnetite assemblage adjacent to the intrusive-limestone contact grading laterally outward through an intermediate chalcopyrite-bornite zone to a peripheral chalcopyrite-pyrite-sphalerite $\pm$ galena outer zone (Eastlick, 1968).

Eastlick (1968) identified four types of mineralization at Christmas: 1) bedded replacement deposits, 2) irregular massive replacement deposits near intrusive contacts, 3) pipe-like replacements at structural intersections cutting the Christmas Stock, and 4) vein deposits along fault or shear zones.

Most of the historical production at Christmas was derived from bedded and massive replacement type ores (Figure 5). Bedded replacement ores occur within six or more favorable stratigraphic horizons (ranging from 6 to 60 feet in thickness) in the Pennsylvanian Naco Limestone that extend outward from the intrusive contact for distances of 50 to 400 feet (Eastlick, 1968). The most persistent ore-bearing horizon is the O'Carroll Bed (20 to 30 feet thick) at the base of Devonian Martin Formation, where ores extend outward from the intrusive-sediment contact for distances up to 1,100 to 1,400 feet (Eastlick, 1968). Less permeable hornfels interbeds and intrusive sills acted as aquitards that focused the mineralizing solutions along favorable, carbonate horizons (Einaudi, 1982).

Massive replacement ores are hosted by relatively pure, thick-bedded carbonates of the Mississippian Escabrosa Limestone. The replacement ores are confined to zones, ranging from 150 to 300 feet in thickness and extend up to 100 feet from the intrusive-sedimentary rock contact (Eastlick, 1968).

Skarn gangue mineralogy closely reflects the original composition of the host rock (Perry, 1968). Endoskarns are hosted by the porphyry stock, while exoskarns occur in carbonate lithologies adjacent to the intrusive-wallrock contact.

At Christmas, endoskarns are confined to a narrow zone (up to 10 feet) along the intrusive-sediment contact, which is altered to a garnet-clinopyroxene assemblage accompanied by minor amounts of wollastonite, chlorite, vesuvianite, epidote and anhydrite (Perry, 1968; and Einaudi, 1982).

Calcic exoskarns were formed in limestone horizons in the Naco Limestone and portions of the Escabrosa Limestone (Perry, 1968). They are characterized by reddish-brown garnet with minor amounts of diopside and epidote (Figure 6). Abundant magnetite and pyrite are commonly present with lesser amounts of chalcopryite and bornite. The outer skarn contact is characterized by garnet veins cutting marble, containing erratic concentrations of chalcopryite and sphalerite (Einaudi, 1982).



Figure 6. Magnetite-garnet-chalcopryite-sphalerite skarn in the Naco Limestone from east of the Joker Fault (photo from White and Thoman, 2014)

Magnesium exoskarns were formed in dolomitic lithologies of the Martin Formation and dolomitic horizons of the Escabrosa Limestone (Perry, 1968). They are characterized by

forsterite and abundant amounts of magnetite (5 to 25%), accompanied by brucite, anhydrite, and sulfides. Tremolite and talc are locally present. Late stage serpentine commonly replaces much of the forsterite. A proximal chalcopyrite-bornite assemblage transitions to a distal chalcopyrite-pyrite-pyrrhotite assemblage along the outer skarn-marble contact (Einaudi, 1982).

During contact metamorphism, the conversion of limestone and dolomite to skarn assemblages results in volume changes and variability in grain sizes within the host rock. Open spaces or vugs developed during this process were filled with later minerals, including copper sulfides (Perry, 1968).

Shale and siltstone lithologies adjacent to the intrusive-sediment contact are altered to diopside or biotite hornfels assemblages that are locally cut by sufficient chalcopyrite veining to be considered ore (Einaudi, 1982).



Figure 7. Oxide copper mineralization hosted by the Christmas Stock between the Christmas and Joker faults (photo from White and Thoman, 2014)

In the footwall of the Christmas Fault, skarns hosted by the Naco Limestone have been mostly oxidized to the 300 level of the underground mine. However, oxidation of strongly broken ground between the Joker and Christmas faults (Figure 7) extends down to the 1,600 level (Eastlick, 1968).

Oxidation of primary sulfides in the skarn and intrusive lithologies at Christmas produced an oxide assemblage, which includes chrysocolla, cuprite, tenorite, malachite, azurite, diopside, brochantite, and chalcantite (Eastlick, 1968; and Koski, 1979). Chalcocite enrichment is relatively minor, but locally significant along some fracture zones (Eastlick, 1968).

Adjacent to the Christmas Stock, primary sulfide mineralization in the Williamson Canyon Volcanics has been oxidized to iron oxides with minor amounts of cuprite, malachite and native copper (Koski and Cook, 1982). However, there has been no significant enrichment in these mafic volcanics, due to the apparent neutralizing effects of widespread secondary biotite alteration and possibly plagioclase (White and Thoman, 2014).

3 MINING HISTORY OF CHRISTMAS (1880 TO PRESENT)

3.1 Early History (1880-1902)

Colorful, copper-bearing outcrops exposed in an isolated canyon near the Gila River attracted Dennis O'Brien and William Tweed, who staked the first mining claims at Christmas around 1880 (Tainter, 1948). After working their claims for a short period, they persuaded Dr. James S. Douglas to examine their holdings during one of his early scouting trips to Arizona. Acting as an agent for Phelps, Dodge and Company, Douglas purchased Tweed's claims and acquired an option on O'Brien's holdings in 1882 (Anonymous, 1979 and White and Thoman, 2014).

Phelps, Dodge and Company formed the San Carlos Copper Company to explore and develop its holdings at Christmas (Rickard, 1987). After constructing a wagon road from the Southern Pacific railhead at Picacho, Arizona to the site (a distance of ~70 miles), the San Carlos Copper Company erected two small water-jacket furnaces for treating the ore (Anonymous, 1979). Only a small amount of oxide copper ore was mined and smelted before operations were terminated in 1884, when a government survey revealed the mine was located within the San Carlos Indian Reservation (Rickard, 1987), which had been established in December 1872.

Over the next 18 years, little work was done at the site. However, Phelps Dodge and Company continued intermittent lobbying efforts to restore the district to the public domain. During this period, they also retained the services of a watchman to keep an eye on the property with hopes of relocating and legally filing their mining claims the moment the area was restored to the public domain (Anonymous, 1979).

However, public knowledge of copper resources at Christmas attracted the attention of competitors. The Saddle Mountain Mining Company was organized in May 1902 under the laws of the Territory of Arizona with an initial capitalization of \$250,000 at \$1 per share (Stevens, 1904). They established their main office in Washington, D. C., where their management closely monitored lobbying efforts to restore the Christmas site to the public domain.

3.2 Saddle Mountain Mining Company (1902-1909)

On December 22, 1902, President Theodore Roosevelt signed an Executive Order that returned the Christmas property (Figure 8) to the public domain (Anonymous, 1912). Upon learning this news, the Saddle Mountain Mining Company management telegraphed their representatives in Casa Grande, Arizona, informing them the ground was now open for the location of mining claims. A relay team of horsemen delivered the message to George Chittenden at their Dudleyville mine office late on Christmas Eve (Anonymous, 1979).

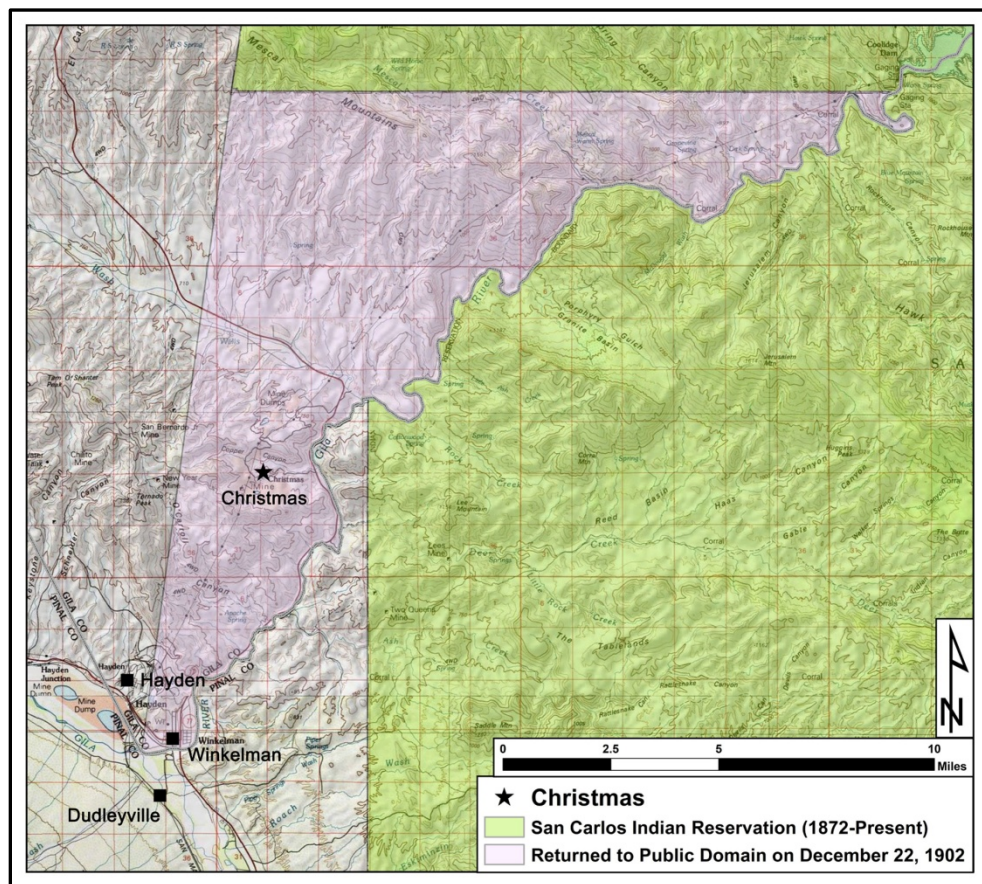


Figure 8. Map showing portion of the San Carlos Indian Reservation, which was returned to the public domain on December 22, 1902 (modified from Welch, 2017)

During the early hours of Christmas morning, George Chittenden (Figure 9), N. H. Mellor, and several associates journeyed to the property. Finding Phelps Dodge's watchman had gone to Globe to celebrate the holiday, they located a group of mining claims for the Saddle Mountain Mining Company that became known as the Christmas property (Anonymous, 1979).

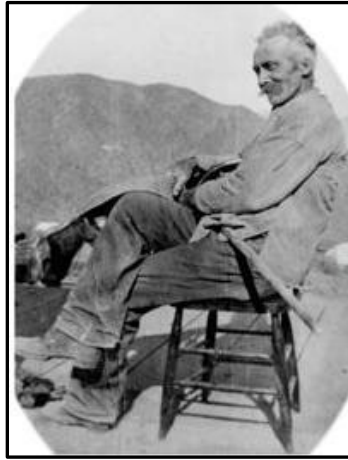


Figure 9. George Chittenden (1849-1939) served as general manager of the Saddle Mountain Mining Company from 1902-1907 (photo from Arizona Historical Society)

Upon learning of this incursion, Phelps Dodge filed a law suit in an attempt to restore its ownership. However, before this suit was brought to trial, Phelps Dodge and the Saddle Mountain Mining Company settled, with Saddle Mountain purchasing approximately 40 of the contested claims for \$160,000 (Burns, 1919).



Figure 10. Early surface workings at Christmas, circa 1900s (photo by Arizona Geological Survey)

Over the next several years, the Saddle Mountain Mining Company gradually expanded its workforce from 25 to 600 as it developed both surface and shallow underground resources at Christmas (Stevens, 1906). Surface workings consisted of a terraced open cut with numerous short tunnels (Figure 10) excavated in the high-wall on each terrace level (Ross, 1925). By early 1905, underground ores had been accessed by several shafts and tunnels, with the deepest workings reaching a depth of 330 feet. Early underground mining operations generally employed open stopes with few pillars, which were ideally suited for the gently dipping, relatively narrow ore shoots (Tainter, 1948).

Coke and other supplies were hauled to this remote mining camp by horse-drawn wagons (Figure 11). Saddle Mountain Mining Company also controlled coal properties in the Lower Deer Creek Basin, located east of the Gila River, which provided coal to fuel the steam engines and heating for the community (Stevens, 1904).



Figure 11. Teamsters hauling coke from the Phoenix and Eastern rail head at Winkelman to Saddle Mountain Mining's Christmas Smelter, circa 1906 (photo from Arizona Geological Survey)

During 1903, a single carload of ore, assaying 9.2% copper was shipped to a smelter (Stevens, 1904). A five day smelting test was conducted in January 1905, using the existing water-jacketed furnace (Rickard, 1987). Employing charges composed of oxide ore from the open cut (65%), pyritic underground ore (20%), slag (5%), and Trinidad coke (10%), these tests produced a matte product, assaying 50-55% copper, 10 ounces of silver per ton and 0.29 ounces per ton gold (Stevens, 1905).

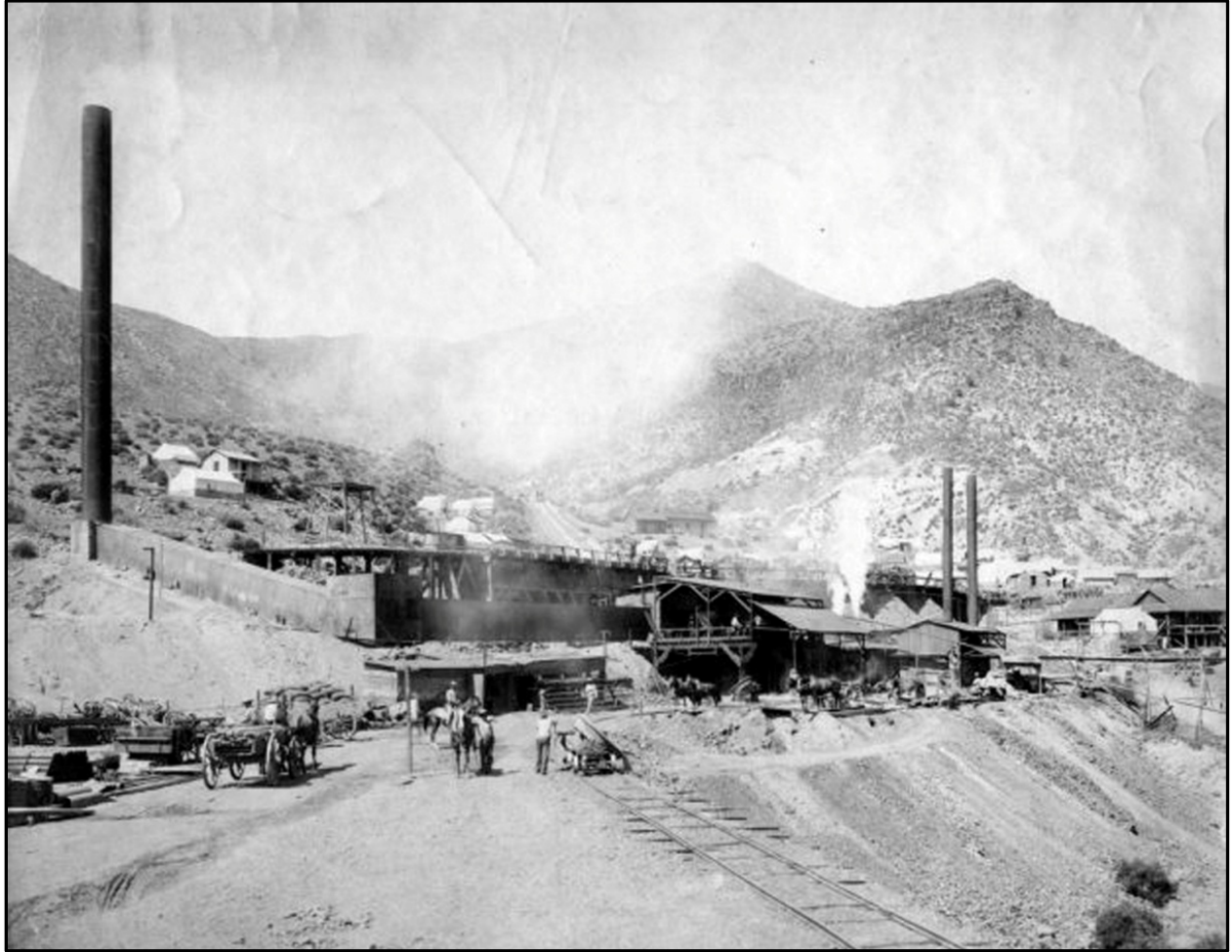


Figure 12. Saddle Mountain Mining Company's Christmas Smelter, circa 1906 (photo from the Arizona Geological Survey)

After obtaining favorable results, the older 30-ton/day smelter was torn down after the test (Rickard, 1987). It was replaced by a 150-ton/day Mitchell blast furnace, which was successfully commissioned in August 1905 (Figure 12). However, interruptions in coke supplies and flooding along the Gila River disrupted operations until January 1906. The new smelter produced a matte product, assaying 60-65% copper, 12 to 14 ounces of silver per ton and 0.35 ounces of gold per ton (Stevens, 1906). This matte product was transported by wagon to the Phoenix & Eastern railhead at Winkelman for shipment to the Boston and Colorado smelter in Denver, Colorado or Arizona Smelting Company's

smelter at Humboldt, Arizona (Stevens, 1906). Early infrastructure (1905-1921) at Christmas is shown in Figure 13.

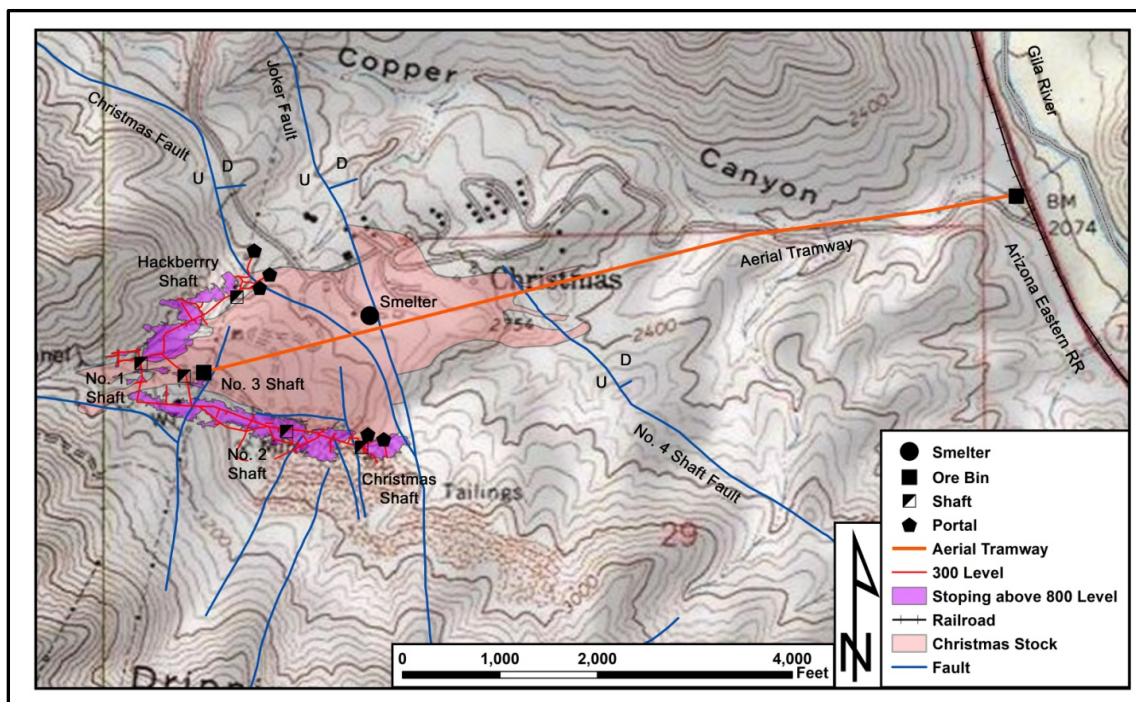


Figure 13. Christmas Mine infrastructure from 1905-1921. Underground workings on the 300 level and stopes above the 800 level have been projected to the surface. Note: All of the mine workings are in the footwall of the Christmas-Joker Fault System along the southern and western contacts of the Christmas Stock. (modified from Peterson and Swanson, 1956; and Koski, 1979)

Although Saddle Mountain Mining's early operations at Christmas greatly benefited from the completion of the Phoenix and Eastern Railroad (acquired by Southern Pacific Railroad in March 1907) to Winkelman in September 1904 (Irvin, 1987), poor management and the high costs of supplies, including coke to fuel the smelter made it marginally profitable (Burns, 1919). During the spring of 1907, a beehive coke oven was constructed for test purposes at their neighboring coal property in Deer Creek Basin in an effort to reduce the cost of providing coke for the Christmas Smelter (Rickard, 1987). Other costs reduction measures included the construction of an early aerial tramway that connected the mines with the smelter (Trennert, 1998). Despite efforts to reduce production costs at Christmas, the Saddle Mountain Mining Company suspended operations in August 1907 due to financial problems that resulted from the collapse of the price of copper from 26.5 cents per pound to 12.5 cents per pound during the Financial Panic of 1907 (Stevens, 1908).

U.S. Bureau of Mines production records show Saddle Mountain Mining's smelter treated 113,322 short tons of ore, averaging 2.48% copper. Total metals production was

approximately 4,540,000 lbs. of copper, 800 ounces of gold and 27,100 ounces of silver (Table 1).

3.3 Gila Copper Sulphide Company (1909-1925)

The Development Company of America, a holding company formed by Frank M. Murphy, organized the Gila Copper Sulphide Company in October 1909 under the laws of Territory of Arizona with capitalization of \$2.5 million at \$10 per share. It also authorized the issuance of \$1.66 million of first mortgage, 6-year 6% bonds that could be converted into stock at the option of the bondholder. The Gila Copper Sulphide Company purchased the Christmas property from the Saddle Mountain Mining Company in October 1909 for \$300,000 in stock and the assumption of its bonded debt (Stevens, 1911).

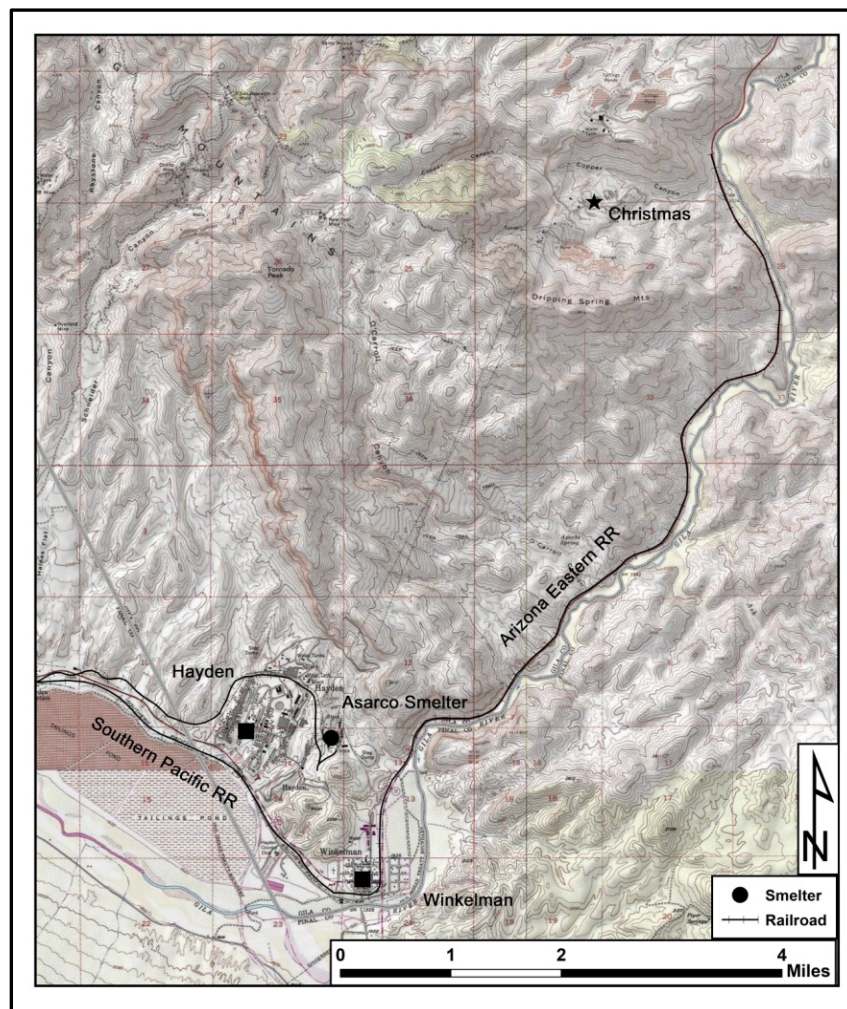


Figure 14. Topographic map showing Southern Pacific Railroad and the Arizona Eastern Railroad, which completed its spur to Christmas in June 1911 (Irvin, 1987)

Over the next several years, the Gila Copper Sulphide Company spent more than \$350,000 on equipment and development to ready the project for production (Weed, 1916). In June 1911, the Arizona Eastern Railroad completed a 7.6-mile branch line from Winkelman to the mouth of Copper Canyon along the Gila River (Figure 14), significantly reducing the transportation costs to American Smelting and Refining Company's (ASARCO) smelter at Hayden, Arizona, which began operations in April 1912 (Heikes, 1913). Despite this effort, funding was insufficient to resume production at Christmas (Burns, 1919).

In May 1915, the Gila Copper Sulphide Company entered a contract with ASARCO to advance funding to resume production at Christmas under the condition ASARCO manage the property until the loan had been repaid. ASARCO also retained the right to smelt the ore for 10 years at a fixed rate (Burns, 1919). In accordance with the contract, ASARCO spent approximately \$176,000 on construction and equipment required to achieve a production capacity of 500 tons per day (Brooks, 1917). ASARCO resumed ore shipments from Christmas in February 1916. ASARCO's loan was repaid in November 1916 (Wilden, 1964).



Figure 15. No. 3 Shaft and hoist house at Christmas, circa 1916 (photo from Anonymous, 1916)

ASARCO's operation at Christmas produced ore from both surface and underground workings that were developed to a depth of 850 feet. The No. 3 production shaft (Figure 15) employed a double-drum steam hoist, converted for electric power, which had a capacity to hoist 500 tons per day from the 800 level. A 1,616-cubic foot per minute Ingersoll-Rand air compressor, located adjacent to the No. 3 Shaft, powered the underground rock drilling and pumping equipment. Well-equipped machine and blacksmith shops were located adjacent to the No. 3 Shaft (Burns, 1919).

Ore hoisted from the No. 3 Shaft was dumped in a 500-ton storage bin, from which it was conveyed to a No. 6 Telsmith gyratory crusher, where it was reduced to minus 5-inches. The crushed ore was manually sorted, picking out the waste rock, before being conveyed to the upper tramway storage bin (Burns, 1919).

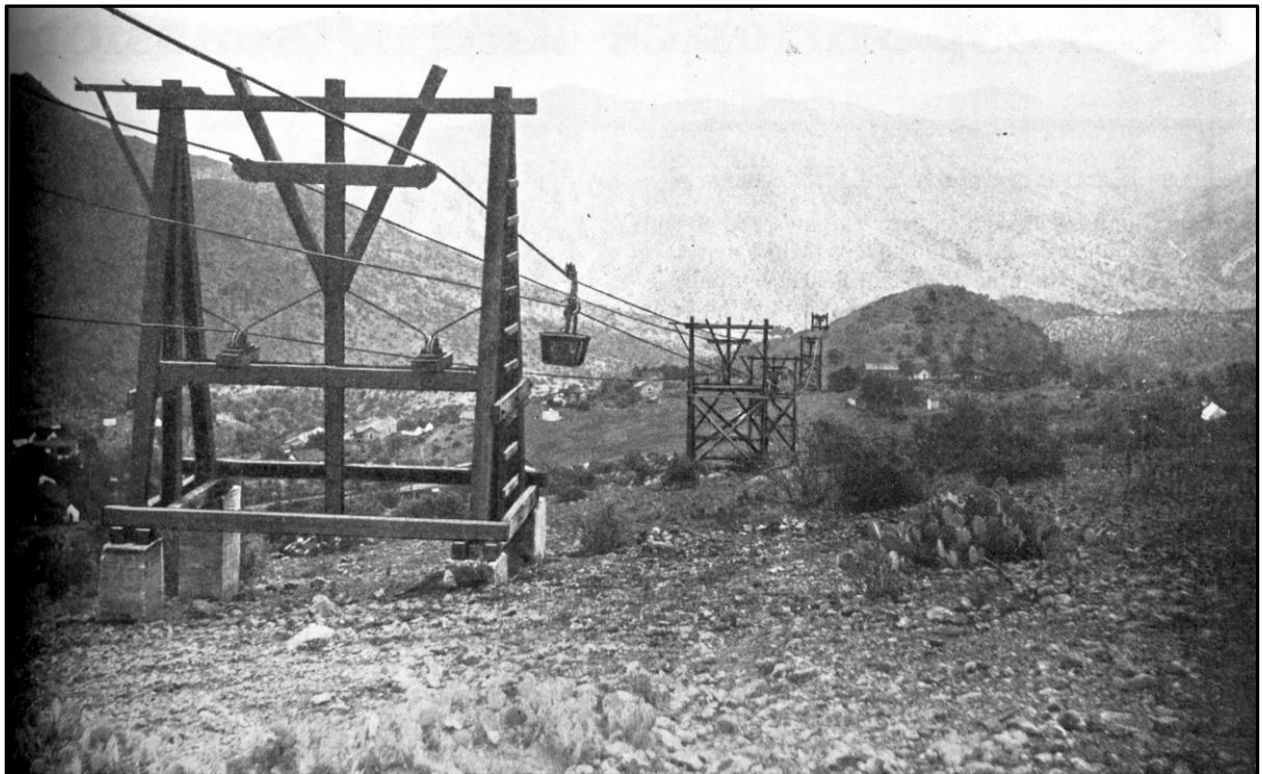


Figure 16. Bleichert aerial tram system at Christmas, circa 1916 (photo from Anonymous, 1916)

A 7,300-foot Bleichert aerial tram system was commissioned in April 1916, which connected the mine with a rail loading facility at Arizona Eastern Railroad terminal along the Gila River (Figure 16). Dropping a vertical distance of approximately 950 feet from storage bin at the No. 3 Shaft to the loading terminal on the Gila River, this aerial tramway was capable of transporting 50 tons of ore per hour. It also powered an electrical generator that provided electricity to the mine. The upper ore bin at the No. 3 Shaft held 250 tons of ore, while the lower bin at the rail loading facility had a capacity

of 1,000 tons. During 1919, its reported cost of operation was 17 cents per ton (Trennert, 1998).

Located approximately 2,000 feet northeast of the No. 3 Shaft, the Christmas mining camp (Figure 17) consisted of company offices and shops, a post office, school, company store, club-house, billiard hall, and sufficient housing of mostly frame construction for several hundred residents. The company store was reported to earn approximately \$1,000 per month (Burns, 1919). Fresh meat, dairy and other agricultural products were provided by neighboring ranches along the Gila River and farming communities around Phoenix. The housing was owned by the Gila Copper Sulphide Company and rented to their employees. Like most early mining camps, housing for management and the engineering staff and their families were segregated from those used by the miners, who were principally of Mexican heritage (Ross, 1925).

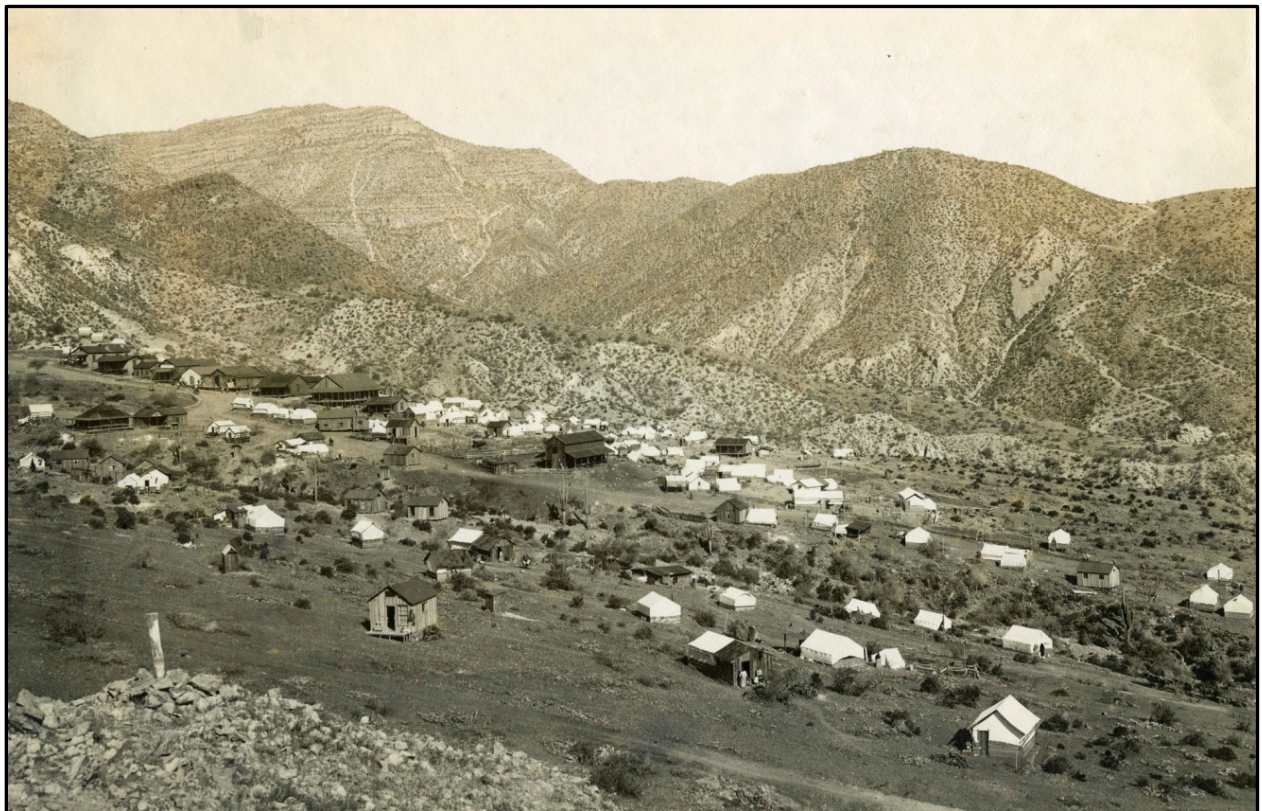


Figure 17. Christmas town site during the early 1900s consisted of a mixture of frame and temporary structures. These temporary structures (known as tent tops) had canvas roofs and wooden sides with dirt or wood floors. Much of this housing could be purchased by the miners as prefabricated and easily assembled kits. By World War I, many of these temporary structures were replaced by frame structures (photo from the Arizona Geological Survey)

After the loan had been paid off in November 1916, ASARCO continued to manage the Christmas project month-to-month at the option of the Gila Copper Sulphide Company for a 10% net earning fee until the operating agreement was terminated on January 20, 1919 (Brooks, 1917). In the meantime, some of the bonds that had been issued after incorporation became due, forcing the Gila Copper Sulphide Company to declare bankruptcy. A receiver was appointed to manage operations for several months until the Gila Copper Sulphide Company was declared solvent by a court decision (Schmitt, 1940). Shipments of direct smelting ores continued to ASARCO's Hayden Smelter until April, 1921, when operations were suspended due to the post-World War I collapse in the price of copper from a high of 32 cents per pound to 12 cents per pound (Jenson, 1924). Following its closure, bondholders instituted foreclosure proceedings against the Gila Copper Sulphide Company (Willden, 1964).

Total smelting ore shipments from 1915 until 1921, totaled 412,596 short tons of ore, assaying 2.82% copper. Metals production totaled approximately 23,153,000 lbs. of copper, 2,900 ounces of gold and 118,300 ounces of silver (Table 1).

3.4 Christmas Copper Company (1925-1938)

In 1925, the Mineral Products Company, a subsidiary of the Iron Cap Copper Company that acquired a controlling interest in the Gila Copper Sulphide Company resumed shipments of high-grade direct smelting ores to ASARCO's Hayden Smelter for its bondholders until December 31, 1925, when it was reorganized as the Christmas Copper Company. The Iron Cap Copper Company owned 75% of the equity in the Christmas Copper Company (Juliha and Meyer, 1932).

Following the closure of its concentrator at the Iron Cap Mine near Globe, Arizona in November 1926, the Iron Cap Copper Company dismantled and relocated the 400-ton/day facility to the Christmas Mine, where it was commissioned in June 1929 (Juliha and Meyer, 1932). A large diesel-powered generator was erected at the rail terminal along the Gila River to provide power for the operation (Tenney, 1927-29).

Run-of-mine ore was fed from a 400-ton ore bin by a 36-inch pan feeder into a primary Tel-smith gyratory crusher followed by a secondary Symons 4-foot cone crusher, which was operated in closed circuit with a shaker screen. The screen undersize (minus 0.75-inch) reported to a 500-ton crushed ore bin. Discharge from the crushed ore bin was directed to a single-stage grinding circuit, consisting of two 5-foot diameter by 10-foot Cole-Bergman ball mills, operated in closed circuit with duplex classifiers. The final ground product reported to a series of Southwestern pneumatic rougher and cleaner flotation cells, which produced a final concentrate product that was delivered via a 4-inch slurry pipeline to a filter plant, located adjacent to the railroad siding along the Gila River, where it was dewatered by a 30-foot diameter thickener and an 8-foot by 8-foot

Oliver drum-type filter prior to shipment to the smelter (Tainter, 1948). Mill recoveries were excellent at more than 90% for sulfide ores and 50% for oxidized material (Schmitt, 1940).

During this period, the town of Christmas continued to grow, reaching a peak population of about 1,000 in 1930. Unlike many western mining camps, gambling halls, brothels and saloons were not present at Christmas; its residents tending to avoid both vice and lawlessness (Anonymous, 2017).

The first post office at Christmas opened on June 17, 1905. It closed and reopened several times over the next three decades, depending on the boom-and-bust nature of the mining district's principal employer. It was often difficult to keep a postmaster at Christmas because his pay was primarily based on the office's stamp sales. However, during the Christmas holiday season, things were much busier. Christmas cards and other packages were commonly sent from many locations across the United States by individuals wanting to have their items re-mailed with a Christmas postmark. With the declining population making continued operations unprofitable, the Christmas post office was permanently closed on March 30, 1935 (Anonymous, 2017).

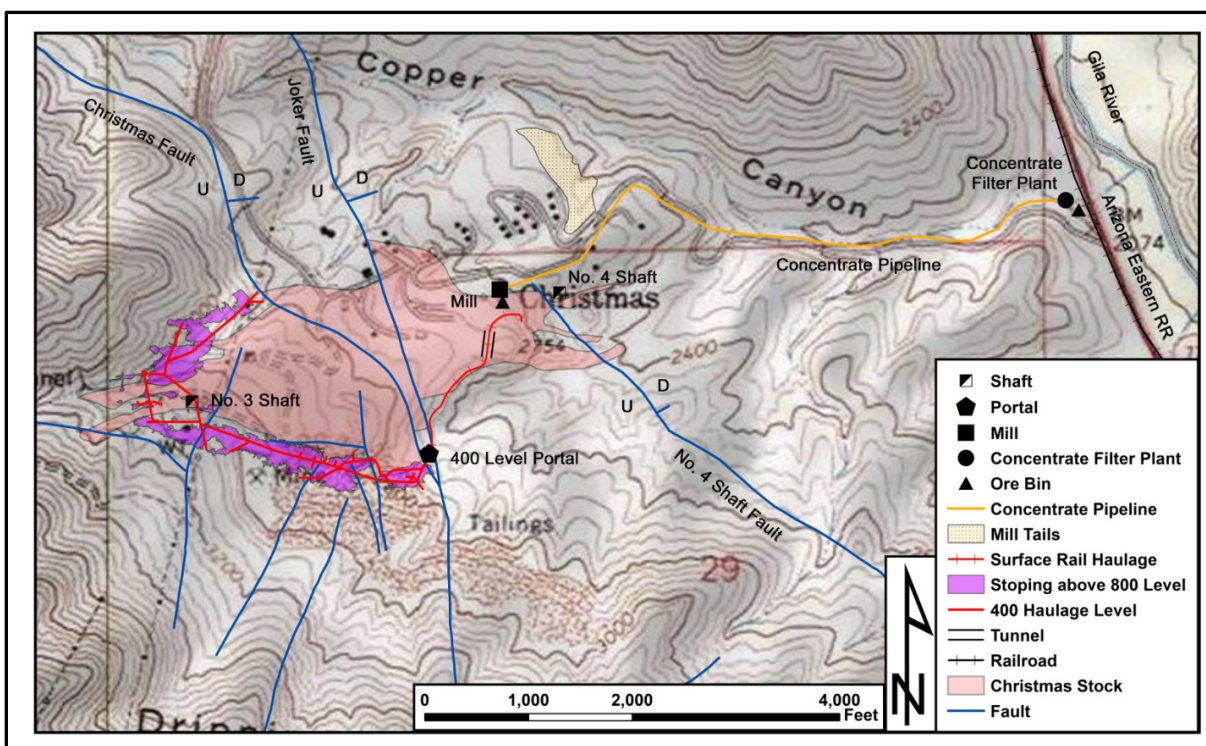


Figure 18. Christmas Mine infrastructure from 1929-1954. Underground workings on the 400 level and stopes above the 800 level have been projected to the surface. Note: All of the mine workings are in the footwall of the Christmas-Joker Fault System along the southern and western contacts of the Christmas Stock. (modified from Peterson and Swanson, 1956; and Koski, 1979)

One of the earliest attempts to evaluate the exploration potential of the eastern, downthrown, hanging wall of the Christmas-Joker Fault System was made during 1930. This involved sinking the No. 4 Shaft (Figure 18) to a depth of 518 feet to explore the favorable Paleozoic limestone hosts that lie beneath thick volcanic cover. A 1,085-foot drill hole collared on the 500-foot level of the No. 4 Shaft failed to reach its intended target (Peterson and Swanson, 1956).

Milling operations were suspended in April 1931 (Gerry and Miller, 1934). During early 1932, all mining and shipments of direct smelting ores were halted at the height of the Great Depression as a result of the precipitous decline in the price of copper from 21.3 cents per pound in March 1929 to 7 cents per pound in May 1932 (Juliha and Meyer, 1933). With the closure of the mine, Christmas' population declined to approximately 100 residents, as many workers and their families left to find employment elsewhere. The aerial tramway was dismantled in 1934.

Between 1925 and 1932, shipments of direct smelting ores totaled 234,398 short tons, averaging 2.37% copper. In addition to the shipments of direct smelting ores, 321,075 short tons of ore, assaying 2.01% copper were treated by the Christmas mill from 1929 to 1931. Total reported metals production was approximately 20,662,000 lbs. of copper, 2,700 ounces of gold and 127,600 ounces of silver (Table 1).

The Christmas Copper Company was reorganized as the Christmas Copper Corporation in 1936. After retimbering the No. 3 Shaft, production resumed during early 1937. Trucks were employed to haul direct smelting ores from the mine site to the Arizona Eastern railhead along the Gila River. However, operations were halted in March 1938 after the price of copper fell below 10 cents per pound (Willden, 1964).

3.5 Sam Knight Mining Lease, Inc. (1939-1953)

Sam Knight acquired a lease on the Christmas property from the Christmas Copper Corporation and resumed shipments of high-grade ores to ASARCO's Hayden Smelter in January 1939 (Miller and Luff, 1940). The excess of iron and lime in Christmas ores made it ideal for fluxing at the Hayden Smelter, bringing a premium price for the ores (Schmitt, 1940). However, the scale of the operation was limited by the wartime manpower shortages and the demand for flux by the Hayden Smelter (Tainter, 1948).

By the late 1930s, ominous events in Europe and Asia suggested the world was rapidly approaching the onset of war. In an effort to prepare America for this possibility, the U.S. Congress passed the Strategic Materials Act in June 1939 (Hughes, 1940). This legislation authorized the U.S. Geological Survey (USGS) and U.S. Bureau of Mines (USBM) to explore for new domestic sources of strategic metals. While copper was not initially included on the list of metals covered by this act, the United States entry into

World War II in December 1941 raised concerns about impending copper shortages leading to its addition to the list of strategic metals in July 1942 (Miller and Meyer, 1943).

As a part of this wartime effort to support the development of known ore deposits and discovery of new ore bodies of strategic minerals, the U.S. Bureau of Mines began an underground diamond drilling program at Christmas in September 1942. At this time accessible reserves hosted by the Naco Limestone were nearly depleted (Perry, 1968). The initial phase of this project consisted of 8 diamond drill holes from the lowest 770-foot level in the mine and was supplemented by a geological mapping program of the existing mine workings by the U.S. Geological Survey (Tainter, 1948). This program discovered an extensive high-grade resource hosted by favorable horizons in the Escabrosa Limestone and Martin Formation.

It was soon realized that ore below the 770-foot level could not be readily accessed due to wartime shortages of manpower and equipment. In January 1943, focus of their exploration efforts was redirected to the 300-foot and 400-foot levels, where an additional 24 drill holes were completed, which delineated a modest reserve that was accessible by the mine's existing infrastructure. Completed in January 1944, this initial drilling program included 32 drill holes, aggregating 5,946 feet drilled (Tainter, 1948).

Drilling below the 770-foot level resumed in February 1945. Seven drill holes totaling 2,575 feet were drilled from the 770-foot level before the project was temporarily suspended in September 1945. Drilling resumed in January 1946, completing two additional holes and deepening an existing hole to 1,523 feet, before it was completed one year later (Tainter, 1948).

From 1939 to 1953, mining operations were conducted from the 908-foot No. 3 Shaft, where the surface plant consisted of a wooden headframe, hoist and compressor building, machine shop, blacksmith shop, timber-framing shed, and several warehouses (Figure 17). The shaft was equipped with a double-drum geared hoist that was driven by a 150-hp induction motor. Two single-deck cages were operated in balance. A change house and lamp house for charging electric mine lamps was located near the portal on the 300 level. The mining camp also had an administrative office, store, school, electric shop, and other dwellings. Many of the older buildings were unoccupied and were in a state of disrepair (Tainter, 1948).

Over the years, mining methods evolved from open stoping with occasional pillars to room-and-pillar methods. The ore-bearing horizons occurred in gently dipping beds, requiring closely spaced pillars. Early mining employed open stoping with sporadic pillars, which resulted in the loss of some stopes, when pressure transmitted through the pillars of overlying mined-out stopes ruptured the barren hanging wall in an

underlying stope. In order to minimize the amount of caving, care was taken to place pillars in the lower stopes directly beneath those in the overlying stopes. Thicknesses of individual ore horizons ranged from 6 to 60 feet, but stopes seldom exceeded 20 feet in height. When completed, permanent pillars measuring 10 to 18 feet square supported the back between openings measuring 10 to 18 feet wide (Tainter, 1948).

Tramming of ore within the mine was performed by hand, where distances were short and tonnages minimal. A 1.5-ton battery-power locomotive with 0.75-ton ore cars was employed on levels where output was greater. All hoisting was performed by the No. 3 Shaft. Ores mined below the 400 level were hoisted in ore cars to the 300 level, where it were dumped into an ore pass adjacent to the shaft station and dropped to an ore bin located above the 400 level. All ores mined above the 400 level were gravity feed to the ore bins servicing the 400 level (Tainter, 1948).

On the main haulage level (400 level), trains consisting of a 3.5-ton battery-powered locomotive and ten to twelve 3-ton side-dump ore cars transported the ore to the surface via the 400 level adit. There it was dumped in a 55-ton surface ore bin, located approximately 1,600 feet north of the 400 level portal (Figure 18). Mine waste was hoisted to the collar of the No. 3 Shaft, where it was deposited on the waste dump. From the surface bin, ore was hauled by a 6-ton dump truck operated by a contractor to the railhead, a distance of approximately 6,000 feet (Tainter, 1948).

Shipments of siliceous copper tails from the old milling operation to ASARCO's Hayden Smelter began during 1951. Sam Knight Mining Lease, Inc. operated the Christmas property until the end of June, 1953 and shipped 3,633 tons of direct smelting ore averaging 4.40% copper and 10,110 tons of mill tailings to the Hayden smelter during the first six months of the year. Prior to 1953, most of the production at Christmas was derived from the middle member of the Naco Limestone (Eastlick, 1957).

Total direct smelting shipments by Sam Knight Mining Lease, Inc. from January 1939 through June 1953 totaled 383,092 short tons of ore, averaging 2.32% copper and 34,957 short tons of mill tails. Metals production totaled about 17,753,000 lbs. of copper, 1,800 ounces of gold, and 93,200 ounces of silver (Table 1).

3.6 Riviera Mines Company (1953-1954)

In July 1953, Allison Steel Manufacturing Company entered a lease agreement with an option to purchase the Christmas property that required an expenditure of \$250,000 by July 1954. Once Allison Steel recouped its investment, Sam Knight Mining Lease received a 4.5% net smelter royalty with a minimum annual royalty payment of \$37,500, which could be applied to the purchase of the Christmas property for \$375,000 in ten

years. Allison Steel formed the Riviera Mines Company to manage its day to day operations at Christmas.

Prior to World War II, there was relatively little stockpiling of strategic and critical minerals such as copper. In response to shortages experienced during the war, the U.S. Congress passed the Strategic and Critical Materials Stock Piling Act in 1946, with a goal of reducing U.S. dependence on foreign sources for supplies of strategic and critical minerals during a national emergency. However, few stockpile objectives had been met by the start of the Korean War in June 1950. In September 1950, U.S. Congress passed the Defense Production Act to rectify this situation. The goals of this assistance program were achieved by long-term market guarantees and changes in the tax code (i.e. accelerated tax amortization and increased depletion allowance) (Morgan, 1955).

To protect their investment, Riviera Mines entered an agreement with the Defense Materials Procurement Administration (DMPA) in August 1953 to purchase 3 million pounds of copper at 32 cents per pound by December 31, 1955. Under the terms of this contract, Riviera Mines had an option to sell its production on the open market, if the copper price made it advantageous to do so.

Repairs were made to an air shaft to the 400 level, where a new fan was installed to improve ventilation in underground workings on the lower levels of the mine. Approximately 2,000 tons of copper ore, assaying from 4 to 7% copper was stockpiled at the surface, while one section of the existing 400-ton per day concentrator was rehabilitated. Production resumed in October 1953, shipping about 20 carloads of concentrate to the smelter. A well located near the Gila River supplied water to the operation, which was pumped to the mill via a 6-inch pipeline.

Approximately 165 men were employed, working 3 shifts per day on a six day work week. Its workforce elected not to be represented by a union. Housing conditions were improved with 13 new houses and 25 existing houses remodeled. Riviera Mines suspended all milling operations in June 1954.

From October 1953 through June 1954, Riviera Mines milled 37,620 short tons of ore, assaying 3.76% copper. Reported metals production during this period, totaled approximately 2,260,000 lbs. of copper, 200 ounces of gold, and 7,600 ounces of silver (Table 1).

3.7 Inspiration Consolidated Copper Company (1954-1988)

In December 1953, Inspiration Consolidated Copper Company began discussions with Allison Steel about acquiring its Christmas property, which required considerable

exploration and development before copper resources in the Escabrosa Limestone and Martin Formation could be profitably extracted. These negotiations led to an option agreement around June 1954; Inspiration agreed to fund an underground exploration program at Christmas prior to deciding whether to purchase the property.

During this period, Inspiration spent approximately \$40,000 per month employing 40 to 70 workers, who excavated drifts and cross-cuts in the lower levels of the mine from which an underground diamond drilling program was conducted.

3.7.1 Early Development (1954-1962)

By mid-1955, Inspiration Consolidated Copper Company exercised its option to purchase Allison Steel's Christmas property and began an intensive development program that included both surface and underground diamond drilling during the last half of 1955 (Kelly et. al., 1958).

During 1956, development continued as the No. 3 Shaft was deepened from the 916-feet to 1,450-feet with workings established on the 1,100, 1,300 and 1,400 levels (Bogert, 1960). Underground access was made to evaluate the potential for high-grade ores of the O'Carroll horizon at the base of the Martin Formation. Diamond drilling continued with strong emphasis placed on short underground drill holes (Kelly et. al., 1958).

While a decision to proceed with the development of the Christmas property was delayed due to low copper prices, mine development continued at a reduced level during the last half of 1957 and much of 1958. A new hoist and headframe were installed on the No. 3 Shaft and the small on-site mill was renovated to conduct metallurgical testing on development ores (Kerns et. al., 1959). The No.3 Shaft was deepened from 1,450-feet to 1,682-feet during the fall of 1958 (Bogert, 1960).

Inspiration Consolidated Copper Company announced plans to complete the development of its Christmas property in December 1958. This program included the sinking of a new production shaft and construction of the necessary plant and surface infrastructure required to bring the property into production at rate of 4,000-tons per day (Kerns, et. al., 1959). As of December 31, 1958, proven and probable ore reserves at Christmas totaled 20,062,000 tons, averaging 1.83% copper (Inspiration Consolidated Copper Company, 1959).

Underground development was accelerated during 1959, proceeding without interruption during the year. In July 1959, the test mill facility began processing development ores at a rate of 100 tons per day, in order to obtain data required to design the metallurgical flow sheet for the planned commercial facility (Kerns, et. al., 1960).

Located on the ridge line north of the ore body, the 3-compartment, concrete-lined McDonald production shaft (Figure 19) was collared in December 1959. It had a 169-foot high, steel headframe built to specifications by the Allison Steel Company and was erected by the Van Dyke and Dail Construction Company. This circular shaft had three compartments; two 5 foot by 6-foot compartments for hoisting ore and a single 11-foot by 6-foot compartment for men and equipment (Bogert, 1960).



Figure 19. McDonald Shaft (also known as the No. 9 Shaft), circa 1960s (photo from the Arizona Geological Survey)

The sinking of the McDonald Shaft continued during 1960 as the excavation of an additional 1,431 feet of development drifts and raises were completed during the year (Kerns, et. al., 1961). Also collared during 1960, the 12-foot diameter, concrete-lined No. 6 ventilation shaft was completed to a depth of 1,205 feet in 1961, greatly improving working conditions on the 1,600 haulage level, which was used to transport the ore from the mine to the McDonald Shaft (Larson, 1962). The McDonald Shaft was completed to a total depth of 1,793 feet in April 1961 (Larson, 1962). A photo of the double-drum hoist and steam turbine in the hoist house is shown in Figure 20.

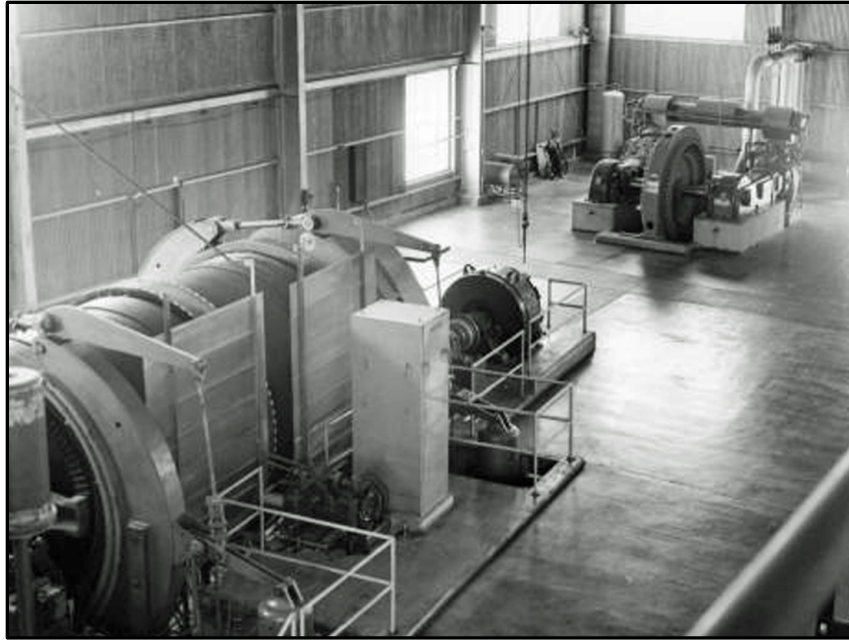


Figure 20. Double-drum hoist and steam turbine in hoist house, circa 1960s (photo from Arizona Geological Survey)

Construction of facilities for crushing, conveying and concentrating the ore was nearing completion by the end of 1961. Tailing dams were laid out and initial berms constructed (Larson, 1962). Underground access was provided by workings on the 1,300, 1,400, and 1,600 levels. Inspiration Consolidated Copper re-evaluated its plans to ship its concentrates to a smelter, eventually deciding to truck them to its Miami Smelter, a distance of 36 miles. This decision resulted in the abandonment of the Arizona Eastern Railroad (now owned by Southern Pacific RR) spur to Christmas during 1961.

3.7.2 Underground Operations (1962-1966)

Inspiration Consolidated Copper commissioned its mill on September 30, 1962 and by the end of the year was mining at a rate of 1,400-tons per day. Initial production was initially derived from development drifting in two stoping areas. Only minor difficulties were encountered with starting the mill, which had a rated production capacity of 4,000-tons per day. Copper recoveries and grade of concentrates were better than those forecasted from earlier metallurgical testing (Larson, 1963). Figure 21 shows mine infrastructure for the period, 1962 until 1981.

By mid-1963, efforts to achieve production capacity of 4,000-tons per day failed due to unforeseen ground support problems, which limited the amount of sulfide ore that could be supplied to the concentrator (Larson, 1964). Furthermore, while mining confirmed ore grades determined by their diamond drilling program, the actual grade of the ore extracted was less, due to irregularities in the ore bodies and more extensive faulting

than was originally anticipated (Larson and Biggs, 1965). This made it necessary to mine close to or in the footwall or hanging wall during stope development, resulting in dilution of the ores (Larson, 1964). Ores were extracted using a modified room-and-pillar method.

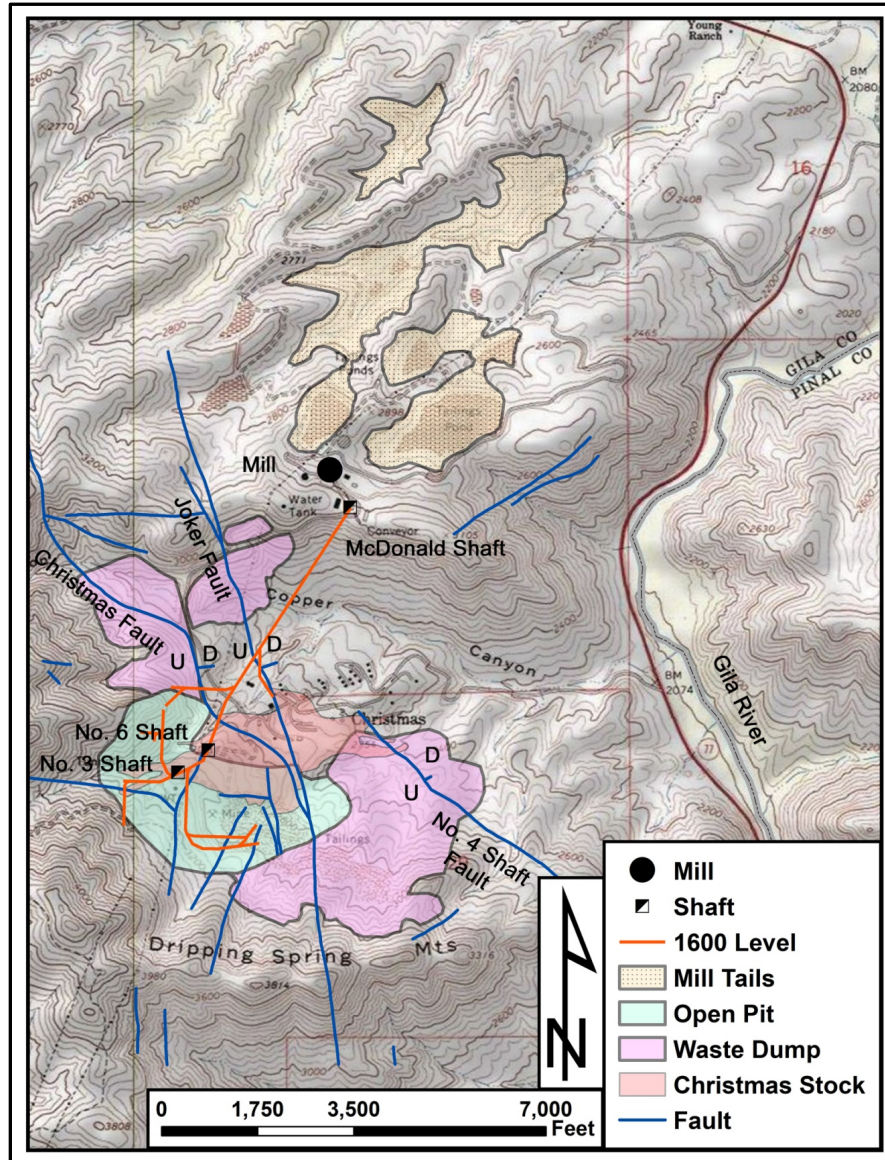


Figure 21. Christmas Mine infrastructure from 1962-1981. The 1600 Level workings have been projected to the surface. Note: The open pit and underground mine occur in the footwall of the Christmas-Joker Fault System along the southern and western contacts of the Christmas Stock. (modified from Koski, 1979)

Underground mining operations were temporarily curtailed during early 1965 due to ground movement on the 1,300 level. After extensive repairs, mining resumed, using smaller stopes that were immediately backfilled with coarse mill tails and material from

surface dumps after mining was completed (Larson and Henkes, 1967b). To make up production short falls from the underground operation, limited open pit production began in October 1965. In September 1966, all underground mining operations at Christmas ceased after extracting approximately 3 million tons (~1.5% copper) of ore since start-up during the fall of 1962.

3.7.3 Exploration Success

Prior to the late 1960s, scientific studies of the district classified Christmas as a pyrosomatic or contact metamorphic type deposit (Ross, 1925; Peterson and Swanson, 1956; Eastlick, 1957; and Willden, 1964). Eastlick (1968) and Perry (1968) noted its similarity to other known porphyry copper systems during the late 1960s.

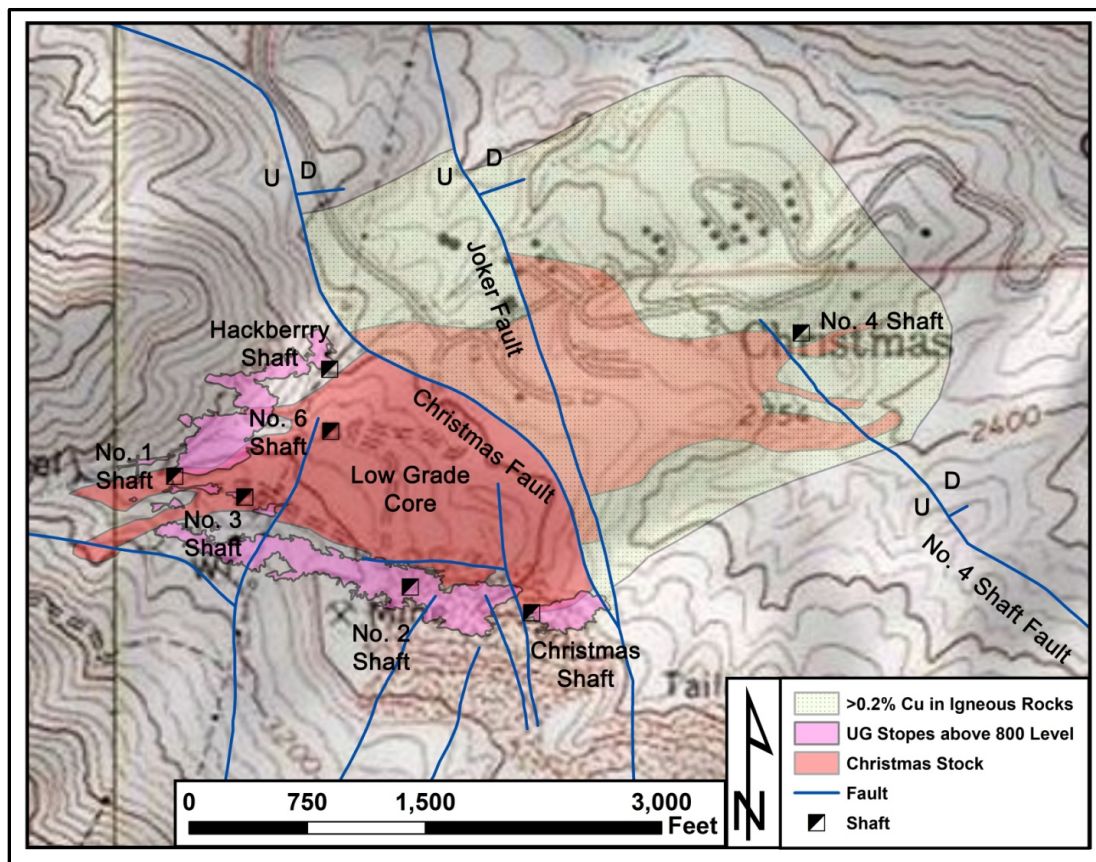


Figure 22. Distribution of porphyry copper mineralization at Christmas projected to the surface. Disseminated and stockwork mineralization is hosted by the Christmas Stock and Williamson Canyon Volcanics in the eastern hanging wall of the Christmas-Joker Fault System. Much of the Christmas Stock in the footwall of the Christmas Fault is located in the low-grade core of the system with high-grade copper-bearing skarn distributed along its western and southern contacts (modified from Koski and Cook, 1982)

The late recognition of Christmas as a porphyry copper system appears to be related to its early history, when development of the deposit was focused on the high-grade skarn deposits located in the western footwall of the Christmas Fault (Figure 22). The significance of sparsely disseminated copper sulfides and quartz-K-feldspar-chalcopyrite veining in the weakly mineralized (<0.1% copper) Christmas stock in this area was not appreciated at that time. Little is noted in the early scientific literature about the presence of copper in the hanging wall of the Christmas-Joker Fault System (White and Thoman, 2014).

An understanding of the true nature of the copper mineralization at Christmas began to change as the Inspiration Consolidated Copper Company readied the mine for production during the early 1960s. During this time, the 1,600 haulage level was excavated, connecting the McDonald Shaft with the underground workings in the western footwall of the Christmas Fault. During the course of this activity, disseminated and stockwork porphyry-style mineralization and alteration hosted by the Christmas Stock and Williamson Canyon Volcanics in the eastern, downthrown hanging wall of the Christmas-Joker Fault System was discovered. Subsequent exploration drilling in this area by Inspiration Consolidated Copper Company (1975) delineated a large low-grade resource (Figure 22), which represents the upper level of the porphyry copper system at Christmas (Koski, and Cook, 1982).

3.7.4 Open Pit Operations (1966-1981)

In late September 1966, operations were halted due to a strike at Inspiration's Arizona operations. When production resumed in mid-October 1966, the open pit was the sole source for copper ores at Christmas (Larson and Henkes, 1967a).

Early development of the near surfaces ores was constrained by the small size of the open pit. This development occurred over slow incremental stages, because no stripping of overburden had been completed prior to their decision to transition from underground to surface mining (Larson and Henkes, 1967a). Initial stripping ratios were high and remained high (waste to ore ratio - 3.1:1 to 5.8:1) throughout much of the remaining life of the operation (Greeley, 1978; and Niemuth, 1982).

The presence of considerable amounts of oxide copper from the open pit operation also required modifications to the Christmas concentrator, which had been originally designed to treat high-grade sulfide ores from the underground operation (Larson and Henkes, 1967a). Recovery of copper from the oxide ores by leaching proved unfeasible due to the high carbonate content of the ores. Despite efforts to improve copper recoveries, overall copper recoveries declined from 85-90% for the underground sulfide ores to 66 to 77% for the mixed oxide-sulfide ores derived from the surface operations (Greeley, 1978; and Niemuth, 1982).

A prolonged strike led by the United Steelworkers of America against major U.S. copper producers, including Inspiration Consolidated Copper Company, halted all mining operations at Christmas from July 1967 until April 1968 (Larson and Henkes, 1970).

During the early 1970s, open pit operations at Christmas employed ten 35-ton haul trucks, two 6-cubic yard front end loaders, and two truck-mounted blasthole drills. A mixture of solid ammonium nitrate prills and diesel fuel (ANFO) was used to break the rock. The ore was transported approximately 8,400 feet to an ore bin located adjacent to the McDonald Shaft, where a two-stage crushing circuit reduced it to a 0.75-inch product before reporting to concentrator (Dayton and Jackson, 1974).

A two-stage grinding circuit at the Christmas concentrator employed a single 11-foot diameter by 16-foot rod mill followed by a two 11.5-foot diameter by 14-foot secondary ball mills that were operated in closed circuit with cyclones classifiers. The cyclone overflow (undersize) was channeled to a flotation circuit, where a sulphidizing agent (NaHS) was added to enhance recovery of the copper from the oxidized fraction of the mill feed. The final copper concentrates were hauled by truck to Inspiration Consolidated Copper's smelter at Miami (Dayton and Jackson, 1974).

All operations at Christmas were suspended on July 1, 1977 due to a strike, which impacted all of Inspiration's Arizona copper operations. When the strike was settled on August 26 1977, operations at Christmas remained suspended pending improvement in the price of copper (Arundale, 1981). With the improvement in the price of copper from 60.6 cents per pound to 97.3 cents per pound (Schroeder and Jolly, 1980; and Jolly, 1980), Inspiration Consolidated Copper resumed operations at Christmas in April 1979 (Burgin, 1981). The price of copper rose to a high of \$1.33 per pound in February 1980, but declined over the next 22 months to 79 cents per pound in December 1981 (Butterman, 1982), resulting in Inspiration Consolidated Copper's decision to halt all operations at Christmas. On January 2, 1982, approximately 250 employees were laid off and the property was placed on caretaker status (Burgin, 1984).

Between September 1962 and December 1981, Inspiration Consolidated Copper milled 24,222,440 short tons of ore, assaying 0.79% copper. Metals production totaled about 291,789,000 lbs. of copper, 46,400 ounces of gold and 1,754,000 ounces of silver (Table 1).

At the time of its closure, Inspiration Consolidated Copper reported open pit reserves of 7,567,000 short tons, averaging 0.63% copper and underground reserves of 20,131,000 short tons, averaging 1.78% copper (Inspiration Consolidated Copper Company, 1982).

Table 1. Reported production from the Christmas Mine, 1905-1981 (modified from U.S. Bureau of Mines data)

Year	Direct Smelting Ore Short Tons	Milled Ore Short Tons	Retreated Mill Tails Short Tons	DSO Cu %	Mill Cu %	Cu Conc. & DSO Lbs.	Cu Mill Tails Lbs.	Total Copper Lbs.	Au Troy Oz.	Ag Troy Oz.
1905	11,219	0	0	2.48		450,000	0	450,000	93	3,200
1906	58,361	0	0	2.48		2,338,492	0	2,338,492	437	16,410
1907	43,742	0	0	2.48		1,751,264	0	1,751,264	254	7,453
1908	0	0	0			0	0	0	0	0
1909	0	0	0			0	0	0	0	0
1910	0	0	0			0	0	0	0	0
1911	0	0	0			0	0	0	0	0
1912	0	0	0			0	0	0	0	0
1913	0	0	0			0	0	0	0	0
1914	0	0	0			0	0	0	0	0
1915	2,144	0	0	5.12		219,694	0	219,694	15	1,051
1916	71,788	0	0	2.87		4,120,631	0	4,120,631	503	19,383
1917	90,358	0	0	2.68		4,850,488	0	4,850,488	626	23,868
1918	90,869	0	0	2.93		5,333,421	0	5,333,421	649	25,727
1919	92,631	0	0	2.94		5,329,957	0	5,329,957	661	29,846
1920	62,510	0	0	2.54		3,178,477	0	3,178,477	417	17,689
1921	2,296	0	0	2.65		120,633	0	120,633	17	752
1922	0	0	0			0	0	0	0	0
1923	0	0	0			0	0	0	0	0
1924	0	0	0			0	0	0	0	0
1925	6,460	0	0	2.63		339,346	0	339,346	35	1,678
1926	44,142	0	0	2.72		2,303,185	0	2,303,185	226	11,391
1927	37,086	0	0	2.51		1,805,112	0	1,805,112	155	11,109
1928	37,928	0	0	2.32		1,703,600	0	1,703,600	172	11,970
1929	51,056	78,048	0	2.16	1.97	4,736,770	0	4,736,770	711	33,515
1930	34,363	182,241	0	2.10	2.04	6,924,735	0	6,924,735	1,007	38,806
1931	18,323	60,786	0	2.31	1.97	2,594,617	0	2,594,617	399	17,476
1932	5,040	0	0	2.53		254,621	0	254,621	17	1,671
1933	0	0	0			0	0	0	0	0
1934	0	0	0			0	0	0	0	0
1935	0	0	0			0	0	0	0	0
1936	0	0	0			0	0	0	0	0
1937	30,170	0	0	2.46		1,470,000	0	1,470,000	96	9,650
1938	6,098	0	0	2.66		314,691	0	314,691	19	2,330
1939	24,790	0	0	2.19		1,055,380	0	1,055,380	119	6,500
1940	25,871	0	0	2.32		1,200,000	0	1,200,000	73	5,616
1941	35,791	0	0	2.16		1,545,000	0	1,545,000	106	9,675
1942	39,837	0	0	2.09		1,668,337	0	1,668,337	120	10,838
1943	27,330	0	0	2.08		1,107,215	0	1,107,215	82	5,670
1944	21,987	0	0	1.94		855,073	0	855,073	65	3,800
1945	19,260	0	0	1.92		740,042	0	740,042	58	3,546
1946	19,921	0	0	1.95		775,939	0	775,939	86	4,400
1947	26,637	0	0	2.03		991,100	0	991,100	77	5,619
1948	32,715	0	0	2.22		1,414,530	0	1,414,530	232	6,710
1949	31,741	0	0	2.64		1,637,000	0	1,637,000	222	7,094
1950	24,007	0	0	2.86		1,340,000	0	1,340,000	168	5,327
1951	30,305	0	6,682	2.70		1,577,000	72,000	1,649,000	242	9,771
1952	19,267	0	18,165	3.16		1,182,350	185,707	1,368,057	148	6,987
1953	3,633	13,018	10,110	4.40	3.96	1,135,300	96,000	1,231,300	101	4,106
1954	0	24,602	0		3.65	1,435,100	0	1,435,100	147	5,095
1955	0	0	0			0	0	0	0	0
1956	0	0	0			0	0	0	0	0
1957	0	0	0			0	0	0	0	0
1958	0	0	1,660			0	15,700	15,770	0	79
1959	0	11,089	9,000		1.65	293,500	67,600	361,100	53	2,199
1960	0	17,052	13,952		1.64	448,400	71,600	520,000	66	2,896
1961	0	0	14,069			0	50,200	50,200	0	507
1962	0	129,617	0		1.36	3,175,400	0	3,175,400	522	24,115
1963	0	658,609	0		1.72	20,232,893	0	20,232,893	2,740	108,066
1964	0	953,231	10,584		1.49	24,952,471	38,800	24,991,271	3,582	132,875
1965	0	715,671	1,319		1.41	17,281,732	4,700	17,286,432	2,428	87,046
1966	0	934,813	0		1.14	16,390,738	0	16,390,738	2,483	93,389
1967	0	856,926	0		0.73	8,988,344	0	8,988,344	1,774	61,803
1968	0	1,173,407	0		0.90	15,282,665	0	15,282,665	2,747	101,361
1969	0	1,918,641	0		0.77	21,301,261	0	21,301,261	3,507	127,960
1970	0	1,829,122	0		0.63	17,343,153	0	17,343,153	2,014	67,031
1971	0	1,537,883	0		0.65	13,652,047	0	13,652,047	2,083	77,547

Year	Direct Smelting Ore Short Tons	Milled Ore Short Tons	Retreated Mill Tails Short Tons	DSO Cu %	Mill Cu %	Cu Conc. & DSO Lbs.	Cu Mill Tails Lbs.	Total Copper Lbs.	Au Troy Oz.	Ag Troy Oz.
1972	0	1,850,122	0		0.80	22,488,926	0	22,488,926	4,420	139,836
1973	0	1,938,611	0		0.74	19,016,412	0	19,016,412	3,460	140,172
1974	0	1,677,272	0		0.57	13,397,391	0	13,397,391	2,306	87,645
1975	0	1,403,835	0		0.57	11,729,139	0	11,729,139	2,169	89,478
1976	0	1,558,165	0		0.58	13,942,431	0	13,942,431	2,783	104,912
1977	0	963,174	0		0.73	10,386,997	0	10,386,997	1,915	76,027
1978	0	0	0			0	0	0	0	0
1979	0	920,000	0		0.74	12,223,735	0	12,223,735	1,416	58,507
1980	0	1,291,958	0		0.73	13,152,050	0	13,152,050	2,051	97,975
1981	0	1,911,383	0		0.62	16,807,786	0	16,807,786	1,952	78,283
Total	1,179,676	24,609,276	85,541	2.52	0.81	362,286,571	602,307	362,888,878	55,026	2,145,438

3.8 Recent History (1988 to Present)

There has been no significant mining at Christmas since operations were suspended on January 2, 1982 (White and Thoman, 2014). The Cyprus Minerals Company acquired the property through its purchase of the assets of Inspiration Consolidated Copper Company from the Inspiration Resources Corporation in July 1988. The Inspiration and Christmas mining operations were acquired during this transaction for approximately \$122 million (Cyprus Minerals Company, 1990). The Cyprus Minerals Company and Amax, Inc. merged in November 1993 to the form the Cyprus Amax Minerals Company (Cyprus Amax Minerals Company, 1994).

Nearly a century after losing the Christmas property in 1902, the Phelps Dodge Corporation reacquired the property through its merger with Cyprus Amax Minerals in October 1999 (Phelps Dodge Corporation, 2000). In March 2007, Freeport-McMoRan Copper and Gold, Inc. (renamed Freeport-McMoRan, Inc. in 2014) acquired the Christmas property through its merger with the Phelps Dodge Corporation and continues to hold this asset today (Freeport-McMoRan Copper and Gold, Inc., 2008).

Freeport-McMoRan Copper and Gold Company renewed exploration activities at Christmas in 2009. This three-year program included a geophysical survey and eight deep diamond drill holes (depths ranged from 2,500 to 4,400 feet), which were designed to: 1) explore for high-grade sulfide ore hosted by favorable lithologies in the Apache Group; 2) gain a better understanding of the skarn and replacement mineralization in Paleozoic strata around the periphery of the Christmas Stock; and 3) test the continuity of dissemination mineralization (White and Thoman, 2014).

Prior to Freeport-McMoRan's 2011-2012 drilling program, exploration drilling had not confirmed the presence of skarn mineralization in the Paleozoic hosts in the eastern, downthrown, hanging wall of the Christmas-Joker Fault System. This deep drilling program established the presence of copper-bearing skarns around the northern and eastern sides of the Christmas Stock. It also confirmed the presence of higher copper

grades and more penetrative oxidation within the zone between the Christmas and Joker faults (White and Thoman, 2014).

Approximately 40% of the original pulps from previous exploration campaigns were located and re-assayed. More than 1,000 historical drill logs were examined and re-coded to produce a database that was used to yield a consistent and reliable geological model that could be used to make resource estimates (White and Thoman, 2014). As of December 31, 2020, Freeport-McMoRan, Inc. reports a mineral resource at Christmas of approximately 332 million short tons, assaying 0.40% copper, 0.0017 ounces of gold per ton, and 0.032 ounces of silver per ton (Freeport-McMoRan, Inc., 2021).

4 ACKNOWLEDGMENTS

The author thanks Freeport-McMoRan, Inc. for an opportunity to work on its Christmas project during 2012 and subsequently hosting the Arizona Geological Society's Spring Field Trip to the site in April 2014. It was through these opportunities that I became familiar with the geology at Christmas and interested in learning more about its place in Arizona's history.

The author also thanks the Arizona Geological Survey, Arizona Historical Society, Ken Krahulec, Mike Conway, and Jan Rasmussen for the use of many of the photos contained within this article. These photos provide an opportunity to learn about Christmas and help to illustrate what is described in the text.

Early drafts of this paper have been edited by Jan Rasmussen, Ken Krahulec and Mike Conway, greatly improving its presentation. Historical production was compiled from unpublished U. S. Bureau of Mines data provided by Stan Keith.

5 REFERENCES CITED

Anonymous, 1909, Great Porphyry Producers of the West: The Salt Lake Mining Review, v. 11, n. 12, p. 23.

Anonymous, 1912, Executive Orders relating to Indian Reservations from May 14, 1855 to July 1, 1912: Department of the Interior, U.S. Government Printing Office, Washington, D.C., 226 p.

Anonymous, 1916, Photographs from the Field: Engineering and Mining Journal, v. 102, n. 12, p. 514-515.

- Anonymous, 1979, Christmas Mine to Reopen this Week: Daily Arizona Silver Belt, April 19, 1979, 1 p.
- Anonymous, 2017, Was there really a Christmas, Arizona?: West Side Storytellers, v. 36, n. 12, p. 11.
- Arundale, J. C., 1981, The Mineral Industry of Arizona; *in* Minerals Yearbook 1977: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 2 (Area Reports, Domestic), p. 65-80.
- Bateman, A. M., 1950, Economic Mineral Deposits: John Wiley & Sons, New York, 916 p.
- Berger, B. R., Ayuso, R. A., Wynn, J. C., and Seal, R. R., 2008, Preliminary Model of Porphyry Copper Deposits: U .S. Geological Survey Open-File Report 2008-1321, 55 p.
- Bogert, J. R., 1960, Christmas Mine Development Proceeds at Fast Pace: Mining World, v. 22, n. 8, p. 28-29.
- Brooks, E. W., 1917, Christmas Mine Development Report: Unpublished report dated March 1, 1917, 9 p.
- Burgin, L. B., 1981, The Mineral Industry of Arizona; *in* Minerals Yearbook 1978-79: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 2 (Area Reports, Domestic), p. 53-75.
- Burgin, L. B., 1984, The Mineral Industry of Arizona; *in* Minerals Yearbook 1982: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 2 (Area Reports, Domestic), p. 55-76.
- Burns, W., 1919, Report of the Preliminary Examination of the Gila Copper Sulphide Company, Christmas, Arizona: Unpublished report dated March 7, 1919, 47 p.
- Butterman, W. C., 1982, Copper; *in* Minerals Yearbook 1981: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 1 (Metals and Minerals), p. 279-307.
- Cyprus Amax Minerals Company, 1994, Annual Report for Fiscal Year ending December 31, 1993, 70 p.
- Cyprus Minerals Company, 1990, Annual Report for Fiscal Year ending December 31, 1989, 48 p.
- Dayton, S., and Jackson, Jr., D., 1974, Part 2: Inspiration Copper (Ore to Rod), Mining Program Aims at Growth Opportunities: E&MJ, v. 175, n. 8, p. 63-74.

- Eastlick, J. T., 1957, New Developments at the Christmas Mine, Gila County, Arizona: Prepared for presentation at Annual Meeting of the Arizona Section, American Institute of Mining, Metallurgical and Petroleum Engineers, 14 p.
- Eastlick, J. T., 1968, Geology of the Christmas Mine and Vicinity, Banner Mining District, Arizona; *in* Ore Deposits of the United States, 1933-1967: Graton and Sales Volume, J. D. Ridge (ed.), American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., v. 2, p. 1191-1210.
- Einaudi, M. T., 1982, Description of Skarns Associated with Porphyry Copper Plutons; *in* Advances in Geology of the Porphyry Copper Deposits: S. R. Titley (ed.), University of Arizona Press, Tucson, Arizona, p. 139-183.
- Emmons, S. F., 1918, Principles of Economic Geology: 1st Edition, New York, McGraw-Hill, 550 p.
- Freeport-McMoRan Copper and Gold, Inc., 2008, Annual Report for Fiscal Year ending December 31, 2007, 111 p.
- Freeport-McMoRan, Inc., 2021, 10-K Report for Fiscal Year ending December 31, 2020: 216 p.
- Gerry, C. N., and Miller, T. H., 1934, Gold, Silver, Copper, Lead, and Zinc in Arizona; *in* Mineral Resources of the United States in 1931: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., part 1, p. 377-415
- Greeley, M. N., 1978, The Primary Copper Industry of Arizona in 1975 and 1976: Arizona Department of Mineral Resources, Special Report No. 2, 89 p.
- Heikes, V. C., 1913, Precious and Semiprecious Metals in the Western States in 1912 – Arizona; *in* Mineral Resources of the United States, 1912: United States Geological Survey, Part 1 - Metals, p. 536-568.
- Hughes, H. H., 1940, Introduction; *in* Minerals Yearbook, 1940: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., p. VII-X.
- Inspiration Consolidated Copper Company, 1959, Annual Report for Fiscal Year ending December 31, 1958.
- Inspiration Consolidated Copper Company, 1975, Annual Report for Fiscal Year ending December 31, 1974.
- Inspiration Consolidated Copper Company, 1982, Annual Report for Fiscal Year ending December 31, 1981.
- Irvin, G. W., 1987, A Sequential History of Arizona Railroad and Mining Development, 1864-1920; *in* History of Mining in Arizona: J. M. Canty, and M. N. Greeley (eds.), Mining Club of the Southwest Foundation, v. 1, Chapter 11, p. 253-278.

- Jenson, H. A. C., 1924, Copper; *in* Mineral Resources of the United States, 1921: U.S. Geological Survey, Part 1 - Metals, p. 235-281.
- Jolly, J. H., 1980, Copper; *in* Minerals Yearbook 1978-79: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 1 (Metals and Minerals), p. 271-311.
- John, D. A., Ayuso, R. A., Barton, M. D., Blakely R. J., Bodnar, R. J., Dilles, J. H., Gray, F., Graybeal, F. T., Mars, J. C., McPhee, D. K., Seal R. R. Taylor, R. D., and Vikre, P. G., 2010, Porphyry Copper Deposit Model, Chapter B of Mineral Deposit Models for Resource Assessment: U.S. Geological Survey Scientific Investigations Report 2010-5070-B, 169 p.
- Julihn, C. E., and Meyer, H. M., 1932, Copper; *in* Mineral Resources of the United States in 1929: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D. C., part 1, p. 525-580.
- Julihn, C. E., and Meyer, H. M., 1933, Copper; *in* Minerals Yearbook 1932-1933: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., p. 27-52.
- Kelly, F. J., Kerns, W. H., Parker, B., and Ransome, A. L., 1958, The Mineral Industry of Arizona; *in* Minerals Yearbook 1955: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports), p. 113-142.
- Kelly, F. J., Kerns, W. H., and Parker, B., 1958, The Mineral Industry of Arizona; *in* Minerals Yearbook 1956: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3, p (Area Reports), p. 107-144.
- Kerns, W. H., Kelly, F. J., and Mullen, D. H., 1959, The Mineral Industry of Arizona; *in* Minerals Yearbook 1957: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports), p. 103-141.
- Kerns, W. H., Kelly, F. J., and Mullen, D. H., 1959, The Mineral Industry of Arizona; *in* Minerals Yearbook 1958: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports), p. 101-124.
- Kerns, W. H., Kelly, F. J., and Mullen, D. H., 1960, The Mineral Industry of Arizona; *in* Minerals Yearbook 1959: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports), p. 103-128.
- Kerns, W. H., Kelly, F. J., and Mullen, D. H., 1961, The Mineral Industry of Arizona; *in* Minerals Yearbook 1960: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports), p. 97-124.
- Koski, R. A., 1978, Porphyry-Type Alteration and Mineralization of Igneous Rocks at Christmas, Arizona: Ph.D. Dissertation, Stanford University, 196 p.

- Koski, R. A., 1979, Geology and Porphyry Copper-Type Alteration-Mineralization of Igneous Rocks at the Christmas Mine, Gila County, Arizona: U.S. Geological Survey Open-File Report, 79-844, 196 p.
- Koski, R. A., and Cook, D. S., 1982, Geology of the Christmas Porphyry Copper Deposit; *in* Advances in Geology of the Porphyry Copper Deposits, Southwestern North America: S. R. Titley (ed.), University of Arizona Press, Tucson, Arizona, p. 353-374.
- Larson, L. P., 1962, The Mineral Industry of Arizona; *in* Minerals Yearbook 1961: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports), p. 101-129.
- Larson, L. P., 1963, The Mineral Industry of Arizona; *in* Minerals Yearbook 1962: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports), p. 101-136.
- Larson, L. P., 1964, The Mineral Industry of Arizona; *in* Minerals Yearbook 1963: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports, Domestic), p. 99-133.
- Larson, L. P., and Biggs, P., 1965, The Mineral Industry of Arizona; *in* Minerals Yearbook 1964: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports, Domestic), p. 105-133.
- Larson, L. P., and Henkes, W. C., 1967a, The Mineral Industry of Arizona; *in* Minerals Yearbook 1966: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports, Domestic), p. 89-114.
- Larson, L. P., and Henkes, W. C., 1967b, The Mineral Industry of Arizona; *in* Minerals Yearbook 1965: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports, Domestic), p. 87-113.
- Larson, L. P., and Henkes, W. C., 1970, The Mineral Industry of Arizona; *in* Minerals Yearbook 1968: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 3 (Area Reports, Domestic), p. 89-111.
- Lowell, J. D., and Guilbert, J. M., 1970, Lateral and Vertical Alteration Zoning in Porphyry Ore Deposits: Economic Geology, v. 65, p. 373-408.
- Maher, D. J., 2008, Reconstruction of Middle Tertiary Extension and Laramide Porphyry Copper Systems, East-Central, Arizona: Ph.D. Dissertation, University of Arizona, 328 p.
- Miller, T. H., and Luff, P., 1940, Gold, Silver, Copper, Lead, and Zinc in Arizona; *in* Minerals Yearbook 1939: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., p. 179-206.

- Miller, T. H., and Meyer, H. M., 1943, Copper; *in* Minerals Yearbook 1942: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., p. 127-161.
- Morgan, Jr., J. D., 1955, Defense Mineral Policies and Programs of the U.S. Government: Mining Engineering, v. 7, n. 12, (December 1955), p. 1106-1109.
- Neimuth, N. J., 1982, The Primary Copper Industry of Arizona in 1981: Arizona Department of Mineral Resources, Special Report No. 5, 48 p.
- Perry, D. V., 1968, Genesis of the Contact Rocks at the Christmas Mine, Gila County, Arizona: University of Arizona PhD. Dissertation, 229 p.
- Peterson, N. P., and Swanson, R. W., 1956, Geology of the Christmas Copper Mine, Gila County, Arizona: U.S. Geological Survey Bulletin 1027-H, p. 351-373.
- Phelps Dodge Corporation, 2000, 10-K Report for Fiscal Year ending December 31, 1999, 121 p.
- Ransome, F. L., 1919, The Copper Deposits of Ray and Miami, Arizona: U.S. Geological Survey Professional Paper 115, 192 p.
- Reynolds, S. J., Florence, F. P., Welty, J. W., Roddy, M. S., Currier, D. A., Anderson, A. V., and Keith, S. B., 1986, Compilation of Radiometric Age Determinations in Arizona: Arizona Bureau of Geology and Mineral Technology Bulletin 197, 258 p.
- Rickard, F. R., 1987, History of Smelting in Arizona; *in* History of Mining in Arizona: J.M. Canty and M.N. Greeley (eds.), Mining Club of the Southwest Foundation, v. 1, Chapter 9, p. 191-228.
- Ross, C. P., 1925, Ore Deposits of the Saddle Mountain and Banner Mining Districts, Arizona: U.S. Geological Survey Bulletin 771, 72 p.
- Schmitt, H., 1940, The Christmas Copper Mine: Unpublished report to Christmas Copper Corporation dated February, 18, 1940, 23 p.
- Schroeder, H. J., and Jolly, J. H., 1980, Copper; *in* Minerals Yearbook 1977: U.S. Bureau of Mines, U.S. Government Printing Office, Washington, D.C., v. 1 (Metals and Minerals), p. 329-370.
- Seedorff, E., Dillies, J. H., Proffett, Jr., J. M., Einaudi, M. T., Zurcher, L., Stavast, W. J. A., Johnson, D. A., and Barton, M. D., 2005, Porphyry Deposits: Characteristics and Origin of Hypogene Features: Economic Geology, 100th Anniversary Volume, p. 251-298.
- Seedorff, E., Barton, M. D., Stavast, W. J. A., and Maher, D. J., 2008, Root Zones of Porphyry Systems: Extending the Porphyry Model to Depth: Economic Geology, v. 103, p. 939-956.

- Seedorff, E., Barton, M. D., Gehrels, G. E., Valencia, V. A., Johnson, D. A., Maher, D. J., Stavast, W. J. A., and Marsh, T. M., 2019, Temporal Evolution of the Laramide Arc: U-Pb Geochronology of Plutons Associated with Porphyry Copper Mineralization in East-Central Arizona; *in* Geologic Excursions in Southwestern North America: P. A. Pearthree (ed.), Geological Society of America Field Trip Guide 55, p. 369-400.
- Sinclair, W. D., 2007, Porphyry Deposits; *in* Mineral Deposits of Canada: W. D. Goodfellow (ed.), Geological Association of Canada Special Publication 5, p. 223-243.
- Stevens, H. J., 1904, The Copper Handbook, a Manual of the Copper Industry of the World: Houghton, Michigan, U.S.A., v. 4, 778 p.
- Stevens, H. J., 1905, The Copper Handbook, a Manual of the Copper Industry of the World for 1904: Houghton, Michigan, U.S.A., v. 5, 882 p.
- Stevens, H. J., 1906, The Copper Handbook, a Manual of the Copper Industry of the World: Houghton, Michigan, U.S.A., v. 6, 1116 p.
- Stevens, H. J., 1908, The Copper Handbook, a Manual of the Copper Industry of the World: Houghton, Michigan, U.S.A., v. 8, 1500 p.
- Stevens, H. J., 1911, The Copper Handbook, a Manual of the Copper Industry of the World: Houghton, Michigan, U.S.A., v. 10, 1902 p.
- Tainter, S. L., 1948, Christmas Copper Deposit, Gila County, Arizona: U.S. Bureau of Mines Report of Investigations, n. 4293, 58 p.
- Tenney, J. B., 1927-1929, History of Mining in Arizona: Arizona Bureau of Mines, v. 1, 401 p.
- Titley, S. R., 1997, 1997 Jackling Lecture – Porphyry Copper Geology – A late Century View: Mining Engineering, v. 49, n. 7, p. 57-63.
- Trennert, R. A., 1998, Aerial Mine Tramways in Arizona, *in* History of Mining in Arizona: J. M. Canty, H. M. Coggin, and M. N. Greeley (eds.), Mining Foundation of the Southwest, v. 3, Chapter 5, p. 103-112.
- Weed, W. H., 1916, International Edition, The Mines Handbook, An Enlargement of the Copper Handbook: W. H. Weed, New York City, v. 12, p. 1686.
- Welch, J. R., 2017, Earth, Wind, and Fire, Miners, and Genocide in Central Arizona, 1859-1874: SAGE Open, October-December 2017, 19 p.
- White, R. O., and Thoman, M. W., 2014, Arizona Geological Society Spring Field Trip to the Christmas Porphyry Copper Deposit, Gila Co., Arizona: Arizona Geological Society Field Trip Guidebook, Saturday, April 26, 2014, 37 p.

Willden, R., 1964, Geology of the Christmas Quadrangle, Gila and Pinal Counties, Arizona: U.S. Geological Survey Bulletin 1161-E, 64 p.

Wrucke, C. T. 1989, The Middle Proterozoic Apache Group, Troy Quartzite, and Associated Diabase of Arizona; *in* Geologic Evolution of Arizona: J. P. Jenney and S. J. Reynolds (eds.), Arizona Geological Society Digest 17, 239-258.

Back Cover. Upper Photo – Christmas pit showing copper-bearing skarns hosted by Naco Limestone, circa 2014 (photo from Mike Conway)

Lower Photo – Christmas town site (center left) with open pit mine in background, looking south-southwest, circa 2014 (photo from Jan Rasmussen)

