DRILL CORE DATA FOR THE RED MOUNTAIN PORPHYRY CU-MO SYSTEM, HARSHAW MINING DISTRICT, PATAGONIA MOUNTAINS, SANTA CRUZ COUNTY, ARIZONA

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Cover Image: View of intensely weathered advanced argillically and sericitically altered rocks from approximately 300 feet beneath the summit above Red Mountain along drill road looking west. Photo from AZGS archives.

ARIZONA GEOLOGICAL SURVEY

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Abstract

Red Mountain in the Harshaw Mining District near Patagonia, Arizona hosts a significant porphyry copper deposit with minor molybdenum mineralization. The deposit is a largely intact and upright fossil magmatic-hydrothermal system emplaced into Late Cretaceous volcanic rocks with vertical drill holes extending up to 1.5 km (>5,000 feet) below the surface. Between 1962 and 1990 exploration drilling by Kerr-McGee defined several mineral resources at Red Mountain, including a shallow supergene-enriched chalcocite-enargite resource of 100-150 Mt @ 0.31% Cu and 0.02 % Mo, a deep hypogene chalcopyrite(-bornite) resource of 385 Mt @ 0.58% Cu and 0.009% Mo, and a sericitized breccia pipe of 49 Mt @ 1.14 % Cu and 0.025 % Mo (Lecumberri-Sanchez et al., 2013). Additionally, the alunite in the lithocap environment was drilled out in the 1970s out as a prospective resource with 273 Mt of 30% alunite (Vikre et al., 2014).

In 2000, a set of original paper data and drill core from Kerr-McGee and Cominco exploration drilling was donated to the Arizona Geological Survey so it would not be lost to physical deterioration. This report and related products present a digital tabulation of the drilling data, including lithological, mineralogical and alteration descriptions as well as Cu assays. These data cover all of the known mineralized drill holes at Red Mountain. Also included is a digitized geologic map with its associated digital data and a web-based geologic map link to the original documents (https://arcg.is/1fSamP2).

Location, Geology, and Exploration History

The Red Mountain porphyry deposit is located in the northern Patagonia Mountains approximately 2.9 miles (4.6 km) south-southeast of the town of Patagonia in Santa Cruz County. The lowest-elevation foothills lie to the north-northwest at ~4,300 feet (1,322 m) elevation. Red Mountain itself is at 5,847 feet (1,782 m) elevation and is a spur off the southwestern side of the unnamed tallest peak (often erroneously referred to as Red Mountain) at 6,375 feet (1,943 m). A drill road constructed by Kerr-McGee leads to the summit from the southeastern side of the area.

The Red Mountain area is dominated by a succession of Late Cretaceous volcanic rocks. The uppermost unit is the Rhyolite of Red Mountain, a series of fine-grained, interbedded siliceous tuffs, lavas, and volcaniclastic rocks that range in present thickness between 500-2,000 feet (457-609 m). The unit is intensely altered by both hypogene and supergene processes, with microcrystalline quartz, sericite, and kaolinite replacing primary mineral sites. Kistner (1984) reports rare relict textures suggesting that the outcrops examined were originally sparsely porphyritic trachyte lavas and tuffs with 0.5-3 mm K-feldspar laths and 0.1-1 mm clinopyroxene crystals in a matrix of microlites and devitrified glass. The Rhyolite of Red Mountain is the equivalent of the latitic to trachytic tuffaceous volcanic rocks (Red Mountain Volcanics) of Corn (1975) and a rhyolite map unit of Simons (1975) and was proposed by Drewes (1972) to be correlative with the Gringo Gulch Volcanics. Vikre et al. (2014) report a weighted mean U-Pb zircon age of 69.5 ± 0.4 Ma for the Rhyolite of Red Mountain, though note that the youngest zircon cores and tips produce a $^{206}Pb/^{238}U$-$^{207}Pb/^{235}U$ concordia age of ~67.5 Ma.

Stratigraphically beneath the Rhyolite of Red Mountain are a series of trachyandesitic to andesitic lava flows with interbedded tuffs and hornfels (Corn, 1975; Lecumberri-Sanchez et al., 2013). The andesitic lavas in turn stratigraphically overlie a series of silicic to intermediate volcanic rocks that are exposed at the surface to the southwest of the map area (Quinlan, 1986). The full thickness of the units have not been drilled, but are estimated as >3,000 feet (Corn, 1975). Lecumberri-Sanchez et al. (2013) suggests these may be equivalent to felsic volcanic rocks that host Ag-Mn mineralization at Hermosa, where the felsic rocks overly Paleozoic sedimentary rocks. Should those same Paleozoic sedimentary rocks be present at depth beneath Red Mountain, they would represent the potential for deep, high-grade skarn mineralization (Lecumberr-Sanchez et al., 2013). The volcanic succession is intruded by stocks, dikes, and sills of monzonite to quartz monzonite to granodiorite with rare intrusive breccias (Corn, 1975; Vikre et al., 2014). Red Mountain is a largely intact and upright fossil magmatic-hydrothermal system emplaced into Late Cretaceous volcanic rocks with vertical drill holes extending up to 1.5 km (>5,000 feet) below the surface. Historical mineral resources at Red Mountain include a shallow supergene-enriched chalcocite-enargite resource of 100-150 Mt @ 0.31% Cu and 0.02% Mo, a deep hypogene chalcopyrite(-bornite) resource of 385 Mt @ 0.58% Cu and 0.009% Mo, and a sericitized breccia pipe of 49 Mt @ 1.14% Cu and 0.025% Mo (Lecumberri-Sanchez et al., 2013). The supergene resource is hosted in hydrolytically altered volcanic rocks that have been variably described as sericitic and advanced argillic alteration within the lithocap environment (Kistner, 1984; Lecumberri-Sanchez et al., 2013). Additionally, the alunite in lithocap environment was drilled out in the 1970s out as a prospective resource with 273 Mt of 30% alunite (Vikre et al., 2014).

Red Mountain is a vertically zoned porphyry system displaying the classic alteration-mineralization zonation first described by Lowell and Guilbert (1970). Near-surface alteration includes distal propylitic veins of calcite, gypsum, and chlorite-epidote (Kistner, 1984). The center of the surficial expression of the porphyry system is dominated by advanced argillic assemblages including quartz-alunite-kaolinite veins and alunite-quartz-pyrophyllite veins with pyrophyllite-sericite selvages and pyrite(±enargite) as principal sulfide minerals (Kistner, 1984; Lecumberri-Sanchez et al., 2013). Quartz-pyrite(±alunite) veins with sericitic selvages reported by Kistner (1984) would represent the transitional sericitic-advanced argillic alteration type. Classic sericitic veins of quartz-sericite-pyrite continue at depth with vertical extents of ~2,000 feet or more (Corn, 1975). Assemblages of quartz-biotite-magnetite±chalcopyrite represent early potassic alteration that are cut by deeper veins of K-feldspar-anhydrite-quartz-chalcopyrite representing the late potassic alteration assemblage. A high-grade, sericitizied breccia pipe occurs at depth cutting the adjacent potassic veins.

The epithermal mineralization has received very little attention and variably described as pyrite-enargite (Kistner, 1984), enargite-chalcocite (Vikre et al., 2014), and chalcocite-enargite(-covellite)±silicification (Lecumberri-Sanchez et al., 2013). While most past workers only refer to a single supergene blanket, Titley (pers. comm.) in Cook and Porter (2005) reports four to six hematite-rich zones in the leached capping at Red Mountain that are the remnants of previously destroyed supergene blankets.

Published work on Red Mountain has largely been derived from hand sample descriptions and observations from drill core (Corn, 1975; Quinlan, 1986; Lecumberri-Sanchez et al., 2013) or from fluid inclusions (Bodnar and Bean, 1980), though some trace element geochemical and mineralogical data has been published on the deposit (Chaffee, 2020; Horton et al., 2020), as well as a few of modern age dates and whole-rock geochemical analyses from a district-wide study (Vikre et al., 2014).

The Kerr-McGee Corporation began exploring the Red Mountain area in 1961 when Kerr-McGee geologists staked claims, optioned unpatented claims, and began evaluating the property for exploration targets. The first exploration hole was drilled in 1962, with 37 holes drilled between 1962 and 1964 totaling 25,245 feet. These initial holes were relatively shallow, ranging from 201 to 1,855 feet in total depth and initially focused on the “near-surface” supergene chalcocite mineralization (Corn, 1975). In 1969, the first 5,000+ foot hole, DDH-138, was drilled and encountered 360 feet of >0.70 % copper at a depth of 4,410 feet. This led to Kerr-McGee reentering and deepening several previously drilled holes, with 29 holes reaching depths >4,500 feet between 1969 and 1984. In total, Kerr-McGee drilled 82 holes between 1962 and 1988 totaling 204,154 feet (62,226 m). Low copper prices in the 1980’s led to Kerr-McGee ceasing exploration of the deep hypogene deposit; periodic shallow drilling of the chalcocite zone continued through 1989 to maintain unpatented claims. In 1990, five additional reverse circulation (RC) holes were drilled as part of a joint venture between Kerr-McGee and Cominco to evaluate the Cu-Au potential of the “high-level” chalcocite mineralization, bringing the total amount of drilling to 206,416 feet (62,916 m) over 87 holes at Red Mountain (Roe, 2012).

In 2005, Kerr-McGee transferred the Red Mountain deposit and many of their non-petroleum assets to a spin-off company, Tronox. In 2009, Tronox declared bankruptcy. Tronox emerged from Chapter 11 in February 2011, with the Southern District of New York’s U.S. Bankruptcy Court creating numerous environmental trusts and settlement agreements with federal and state environmental agencies. Red Mountain was included with the Multistate Environmental Response Trust with

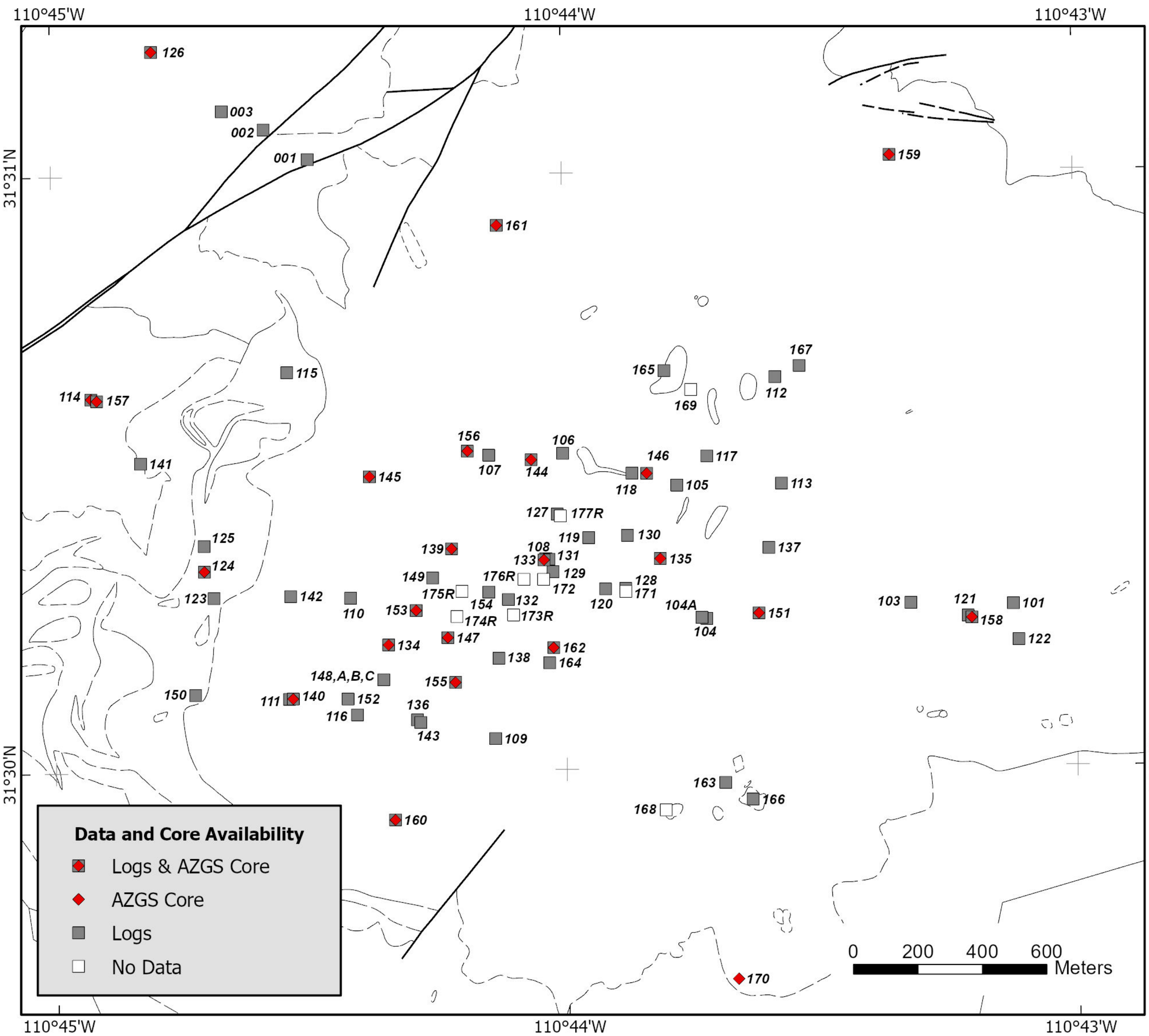


Figure 1. Location of dril holes in the Red Mountain porphyry system. The drill holes are keyed by whether drill logs, skeletonized drill core, both, or none are available at AZGS and utilized as part of this project.

Greenfield Environmental Trust Group appointed as a trustee of the Multistate Environmental Trust Group (Roe, 2012).

Data Sources

In 2000, Kerr-McGee donated skeletonized core from 26 drill holes to the Arizona Geological Survey (Fig. 1). These were accompanied by drill logs for most of the donated holes, as well as for many of the other drill holes, in addition to reports, assay data, maps, and cross sections. In 2005, copies of drill logs, reports, maps, and unskeletonized drill core from several drill holes (DDH-151, DDH-155, and DDH-156) were separately donated to the U.S. Geological Survey. The data donated to the U.S. Geological Survey served as the primary data source for the work by Lecumberri-Sanchez et al. (2013) on the temporal and spatial variation of alteration-mineralization features at Red Mountain via modelling in Vulcan. P. Lecumberri-Sanchez kindly provided all the original documents used in her work, which we cross-referenced with our documents to compile the most comprehensive set of logs and data. Our dataset thus includes all available data for the Red Mountain porphyry system from AZGS and USGS sources.

While the Vulcan model produced by Lecumberri-Sanchez et al. (2013) is not publicly available, the tabulated data that formed the model is publicly available (Lecumberi-Sanchez, 2013, Appendix C). The tabulated data of Lecumberri-Sanchez (2013) and the database in this report vary in regards to the granularity of how details are captured. Lecumberri-Sanchez (2013) captures all lithology and the presence or absence of alteration and ore minerals, but does not capture the abundant notes and commentary provided by the drill logs. The detailed descriptions and qualifications of lithology, alteration, and mineralization are captured in our tabulation.

Assay Data

As many as three sets of assay values are available for some drill holes from Kerr-McGee and Cominco logs. The vast majority of assayed samples are at 5 or 10 foot regular intervals rather than at lithologic or mineralogical breaks. In addition to the assays written on the "simple", "detailed" and Cominco logs, a set of "Assay" documents exists for holes DDH-133 to DDH-165. These appear to be composited assays, with longer intervals and multiple sample numbers listed for each assay value. For many holes in this range, assay values for Au, Ag, Zn and Pb are included. Assays for these elements are not recorded in many of the same intervals in the original Kerr-McGee logs. However, the same sample numbers are used for the same intervals between the Kerr-McGee logs and the "Assay" documents. Thus, it is unclear whether these represent re-assays of composited samples or simply the same original data recorded in different ways. In either case, the "Assay" data are presented in "RedMountain_AZ_Assay.xlsx".

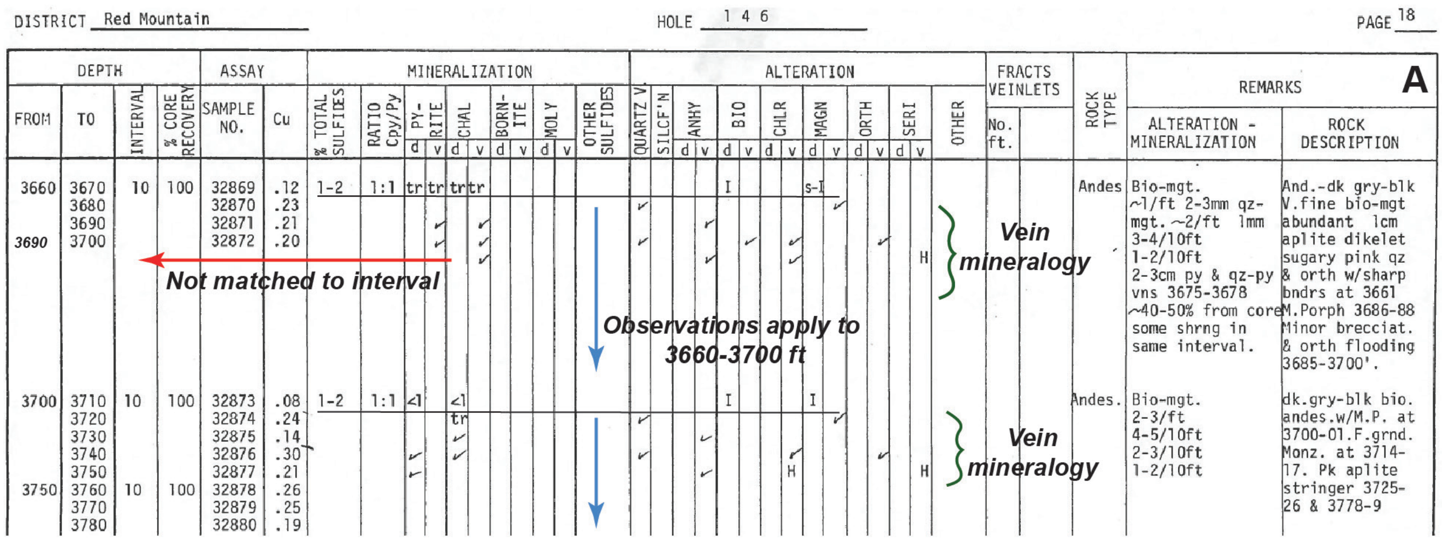
As is often the case with legacy data almost no documentation certifying the original assay values is available. A scan of an original, signed assay certificate document is available only for samples from DDH-148C. This certificate is dated 1977 from "American Analytical and Research Laboratories". Composited assay values from the same samples are hand-written in this document.

In 1989 through 1990, Cominco relogged and re-assayed many of the earlier drill holes, producing a new set of independent observations overlapping the earlier Kerr-McGee logs. Cominco's re-assays in multiple drill holes only extended to a depth of 1000 ft, reflecting their focus on the near surface oxidized deposit. These assays appear to have been done by resampling the core, given the similar, but slightly different interval breaks from the original Kerr-McGee samples. The later Cominco assays and composite assays generally reproduce the values obtained for the original round of assays. In some cases, there are significant discrepancies, where composite and Cominco assays obtained much lower values for the same intervals. We might speculate that this indicates some (not all) of the original core sampled by Kerr-McGee samples were heterogeneous with respect to the distribution of mineralization. Thus, the end users of these data are encouraged to use caution and evaluate the quality of the assay data according to current best practices.

Digitization methodologies and quality control

All physical drill logs, reports, assay data, and maps were scanned at high resolution. Many drill logs from the Kerr-McGee Corporation, classified as "detailed" logs, suffered extensive water and mechanical damage prior to donation to the Arizona Geological Survey. Logs were stored folded in half with dirt accumulated in the creases of the folds, contributing to the deterioration of the material. Documents were carefully unfolded, cleared of any debris, and cleaned before scanning.

Two different types of drill log from the Kerr-McGee Corporation were identified. One type included text observations on the lithology, mineralization, and alteration of each interval, as well as percent core recovery. Assay values for copper and sometimes molybdenum were recorded with original sample numbers. Copper values were mostly reported in weight percent, and molybdenum was reported in ppm. These logs were classified as "simple" logs and were both typed and handwritten. Kerr-McGee simple logs for drill holes DDH-001 to DDH-012 did not contain assay values for copper nor text comments for mineralization and alteration. Drill holes DDH-013 and DDH-016 each had two Kerr-McGree simple drill logs that were compiled into one spreadsheet for the respective drill hole. Some logs were



Mineralization

Borehole _ID	Top Interval	Bot Interval	IntUnits	Total Sulfides %	Ratio Cpy/Py	Pyrite (diss %)	Pyrite (vein %)	Cpy (diss %)	Cpy (vein %)	Born (diss %)	Born (vein %)	Moly (diss %)	Moly (vein %)	Other Sulfides
DDH-146	3660	3670	feet	1-2	1:1	tr	tr	tr	tr					
DDH-146	3670	3680	feet											
DDH-146	3680	3690	feet				present		present					
DDH-146	3690	3700	feet				present| |	present| |	present					
DDH-146	3700	3710	feet	1-2	1:1	<1		<1						
DDH-146	3710	3720	feet					tr						
DDH-146	3720	3730	feet					present						
DDH-146	3730	3740	feet			present		present						
DDH-146	3740	3750	feet			present								

B

Alteration C

Borehole _ID	Top Interval	Bot Interval	IntUnits	Quartz Veining	Silicic	Anhy (diss)	Anhy (vein)	Bio (diss)	Bio (vein)	Chlr (diss)	Chlr (vein)	Magn (diss)	Magn (vein)	Orth (diss)	Orth (vein)	Seri (diss)	Seri (vein)	Other	Comment1
DDH-146	3660	3670	feet					I				S-I							Bio-mgt.
DDH-146	3670	3680	feet	present									present						~1/ft 2-3mm qz-mgt.
DDH-146	3680	3690	feet				present												~2/ft 1mm
DDH-146	3690	3700	feet	present| |			| | present		present| |	present| |	present				present| |		| | H		3-4/10 ft| | 1-2/10 ft 2-3c
DDH-146	3700	3710	feet					I				I							Bio-mgt.
DDH-146	3710	3720	feet	present									present						2-3/ft
DDH-146	3720	3730	feet				present												4-5/10 ft
DDH-146	3730	3740	feet	present							present				present				2-3/10 ft
DDH-146	3740	3750	feet				present				H						H		1-2/10 ft

Figure 2 *An illustration of how we have digitized vein observations when they are written in a gap between intervals (A). In all cases we have combined such vein data with the vein data in a preceding interval, separating data with a double pipe ("||") delimiter (B and C). Note that the vein observations as well as the lithological, mineralogical and alteration data pertain to the larger interval (3660-3700 ft) even though the data is written as though it pertains to the smaller assay intervals (3660-3670, 3670-3680 ft, etc.)*

categorized as "summary" logs, which contained minimal geologic comments and core recovery data. These were digitized along with the "simple" logs. The second type of log reported numerical values for total sulfides, and specific types of alteration were recorded for each interval on a qualitative intensity scale in addition to commentary on lithology, alteration, and mineralization. These logs were classified as "detailed" logs and included both typed and handwritten versions. Kerr-McGee appears to have switched from the "simple" to "detailed" logging style in early 1973.

Cominco relogged a selection of drill holes from DDH-105 to DDH-153, recording quantitative and qualitative observations on lithology, alteration and mineralization. Cominco drill logs reported graphic depictions of the geology and structure of the drill hole that could not be practically digitized. Fracture intensity observations reported, as well as the percentage of oxidation for each interval. Cominco logs also reported sample numbers and assay values of copper. While the log headers show "vol% Cu", this would be highly unconventional, and it is likely that the values are weight percent as is the case with all other assay values in this collection. Types of both mineralization and iron oxides were reported in numerical values, with total percent of iron oxides and total percent of sulfides as well. Types of alteration and the strength of fracturing were both reported on a qualitative scale of weak to total/intense. Intervals were defined by descriptive comments. All Cominco logs were handwritten.

Data from each drill log was entered into a separate spreadsheet and later compiled into the larger datasets that accompany this report. These are as follows: Cominco logs, Kerr-McGee detailed logs, Kerr-McGee simple logs (including summary logs). We kept data from these log types separate, rather than combining into a single dataset, because the style and content of each is markedly different. For example, the detailed Kerr-McGee logs include observations of “anhydrite, biotite, chlorite…” etc. under the category of alteration, while Cominco logs include “Sil., Arg., Serc., Prop.”, etc. under the category of alteration. Thus, the data could not be merged sensibly and is best kept separate.

A set of documents showing graphs of assay values, mostly derived from the “Assay” documents, with minimal notes on lithology and alteration, were also scanned and made available in the data repository. No data from these “Graph” documents were digitized.

A consistent set of standard symbols and codes was developed for qualitative observations recorded in each set of logs. For example, if the strength of silicic alteration is reported as “intense” in the log, this is recorded as “I” in the digitization spreadsheet. This procedure was maintained for lithology codes as well, with each lithology reported having a unique identifier that is consistent across each log (these are listed in the “Codes” tab of each spreadsheet). Blank spaces on the original log were interpreted as “no information” or “not reported” and subsequently represented with a blank, meaning unfilled, cell during digitization. Values reported with a dash, “-“, were interpreted as “none” or “zero” and recorded with a dash in the corresponding cell during digitization. For example, an assay value that is blank was interpreted as “no information” and left blank in the spreadsheet. An assay value reported as a dash was interpreted as “none” or “below detection,” and recorded as a dash in the spreadsheet. In some drill logs, an “H” was reported for an alteration value. This is interpreted as “halo” and is recorded as “H” in the spreadsheet. All assay values were recorded in weight percent during digitization and converted from ppm when necessary. For all logs, text that was illegible was denoted with (*Text unreadable*) in place of the text. Text that was somewhat readable but with uncertainty was written as (*Text*), with the digitizers best guess inside the parenthesis and asterisk. To provide accurate data and preserve the original logs’ information, each log was thoroughly reviewed for quality control after compilation. This was done by checking all data reported with the original log and keeping track of corrections made during the process to determine the amount of error from initial digitization.

Care was taken to produce the exact same intervals in each of the lithology, mineralization, alteration, and assay data tabs. Where intervals did not match for each of these datasets, the intervals were split and data duplicated, to match the interval boundaries.

Tables of independent assay and mineralogical data are available for 32 drill holes. The clean tabulation and typography of these documents allowed for digitization by optical character recognition (OCR). Attempts to use OCR on other typed logs were unsuccessful. The OCR engine “Tesseract” was employed using the PyTesseract Python library. After OCR, each table was checked line-by-line for errors, incorrect characters, and text misalignments.

The logging of vein mineralogy in the Kerr-McGee detailed logs is not perfectly translated into a digital format and the end-user will have to further parse the data to make meaningful use of the vein data. An example of how veins were logged is shown in Figure 2A. Assay samples were collected at 10 ft intervals, but the mineralization, alteration and vein observations are recorded for longer intervals. In the example on the preceeding page, the mineralization, alteration and lithology observations apply to 3660-3700 ft, even though they are recorded in line with the 3660-3670 ft interval. The vein observations are recorded with check marks in the intervals below and apply to the veins recorded in the larger interval, 3660-3700 ft. There is not a different vein type in each 10 ft interval, as might be assumed at first glance. In some cases, there are more vein types (4 in the example below) than there are interval spaces to write in (3), so the vein observations are not assigned to an interval. This presents a challenge for directly transcribing the logs in a digital format; we cannot leave blank intervals to record vein mineralogy. Our solution is to combine vein mineralogy observations that are not in-line with a specific interval with observations in a previous line (or two) with a consistent delimiter. Thus at 3690-3700 ft (see Figure 2B,C) mineralization is recorded as "present||" for pyrite and "present||present" for chalcopyrite, indicating pyrite and chalcopyrite in the third vein type and only chalcopyrite in the fourth vein type. The delimiter is always a double-pipe or "||".

The delimiter solution is not perfect for producing a digital dataset that can immediately be used in mining data software, but it avoids parsing the data in a way that might exclude certain software while being suitable to others. For example, we might have listed all the vein observations in a row, duplicating the larger, true interval for multiple records (3660-3700 ft in this case). However, some applications would not be able to handle this data format. Alternatively, we might have listed veins "horizontally", categorizing them as "VeinType1" to "VeinType5". However, this would result in different vein associations all being categorized as "VeinType1", for example, which may not be desirable depending on how the data is used. Assigning veins to a specific type is clearly an interpretive task, which we have avoided here as it is beyond the scope of this project. It is thus up to the end user to decide how to parse vein data in a suitable way in the Kerr-McGee detailed logs.

Geospatial Data

The original drill hole locations were recorded in both NAD27 State Plane Arizona Central zone (FIPS 0202) and a local mine grid. Sufficient data was recorded in State Plane coordinates and on georeference-able maps that the local mine grid coordinates were not used. An attempt was made to produce a projected coordinate system for the mine coordinates to be used in GIS, however, there was a great deal of scatter between the state plane and mine grid coordinates, so this effort was unsuccessful. Producing a mine grid coordinate system from the available data has a high potential for error and no means of quality control. The collar coordinates (UTM Zone 12N NAD83) tabulated here are either converted from NAD27 State Plane coordinates or taken from georeferenced maps ("RedMtn_AZ_DHSurvey+Alteration.jpg"). Note that in ESRI applications, georeferenced maps using the NAD27 State Plane coordinate system, project with an offset from the standard ESRI basemap imagery when the map/data frame projection is set to NAD27 State Plane (0202). Setting the map/data frame projection to NAD83 UTM Zone 12 appears to correct this offset.

Several relevant maps, including detailed geologic maps, drill hole and sample locations, and downhole survey data are included with this report. The detailed geologic maps (RedMtn_AZ_GeologicMap1/2/3.jpg) are available as georeferenced JPEGs and as digitized USGS GeMS compliant GIS data. While all the geologic data on the map was digitized, much of the orientation data is unidentifiable due to the lack of a map explanation. For orientation symbols with no inclination value, "-99" is recorded in the attribute data.

The only downhole deviation data available is recorded on "RedMtn_AZ_DHSurvey +Alteration.jpg" as points with elevation data. Downhole deviation data is not available for many of the drill holes. From the map, georeferenced X, Y, and Z data were digitized for the downhole surveys, including the collar locations. The collar locations georeferenced with the survey data are consistently offset 2-5m to the WNW from the collar locations based on the coordinates recorded on the drill logs. We have thus made the survey data available in two ways: 1) as the original X, Y, Z positions georeferenced from "RedMtn_AZ_DHSurvey+Alteration.jpg" and 2) recalculated as deviations from the collar locations recorded on the drill logs. The end user may decide which version should be given higher confidence.

New Geochemical Data

Skeletonized core was re-sampled for whole rock geochemistry in select locations to characterize mineralization and alteration geochemistry. Samples were analyzed through the Analytical Chemistry project at the USGS Geology, Geophysics, and Geochemistry Science Center in Denver, CO. In the dataset provided, the "Field No." is coded to the drill hole (first three digits) and the footage (last four digits) at which the sample was collected For example, sample 124_0239 is from DDH-124 at 239 ft. Samples ranged from 25-250g, including no more than 3-4 inches of core for each sample. In some cases, samples were trimmed to better capture the geochemistry of vein and alteration mineralogy, avoiding unaltered host rock. The sample descriptions in the spreadsheet provided indicate the target or goal of each sample.

Geologic Map Unit Descriptions

The digitized geologic map based on a paper map donated in this collection is the most detailed known geologic map of Red Mountain. Authorship is attributed to "DLE Huckins", with Quinlin (1986) attributing his figures 2 and 3 as modified after DLE Huckins (1975). Additional alteration mapping and As and Mo contours were added to the original map by H. Holmberg in 1987 and 1988. The following unit descriptions are taken primarily from Lecumberri-Sanchez et al. (2013) with minor modifications.

Czb – Cenozoic basin-fill deposits (Neogene)
Neogene basin-fill deposits. Designated Qal on the original map.

FZ – Fault Zone (Neogene?)
Narrow zone with breccia symbol fill in two locations. Interpreted to be a fault-related damage or breccia zone contiguous with discrete fault traces along strike.

PEbx – Breccia (Paleocene)
Brecciated bodies of rock are locally mapped at the surface and have previously been described as intrusive breccias (Lecumberri-Sanchez et al., 2013, Fig. 2). A mineralized breccia pipe at depth, intercepted by DDHs 148, 148B, 148C, and 155, is hydrothermal in origin. Thus, the breccia bodies on the map are undifferentiated with respect to their origin and may be hydrothermal, intrusive, or potentially tectonic in origin.

PEgd – Porphyritic quartz monzonite to granodiorite (Paleocene)
Porphyritic intrusive rocks of Red Mountain. Designated "Tp" on the original map. The following description is taken from Lecumberri-Sanchez et al. (2013, J. of Geochemical Exploration). "[D]ikes and irregular masses of monzonite, quartz monzonite, quartz–feldspar porphyry, and intrusive breccias. Mineralized (cpy-bn) quartz monzonite porphyry in the Red Mountain porphyry copper system at the northern end of the range has been dated at 62 Ma (Vikre et al., 2009). These intrusions are fine- to medium-grained porphyries in which the feldspar phenocrysts have commonly been altered to sericite and the matrix to quartz, sericite and pyrite (Kistner, 1984). These units are exposed mainly on the central and western slopes of Red Mountain and in drill core from this area. These intrusions generated a 6–8 mi^2 area of hypogene hydrothermal alteration and mineralization at the present surface, including peripheral propylitic alteration and narrow veins thought to be related to the Red Mountain system (Corn, 1975). A single larger plutonic body at depth has not been identified at Red Mountain."

PEKr – Rhyolite of Red Mountain (Cretaceous-Paleocene)
The rhyolite of Red Mountain. Designated "Tt" on the original map. The following description is taken from Lecumberri-Sanchez et al. (2013, J. of Geochemical Exploration). "The uppermost unit is a resistant complex of individually discontinuous, siliceous, flow-banded and volcaniclastic rocks that is at least 1500 ft thick. Corn (1975) referred to these units as trachytes and latites, whereas Simons (1974) described them as rhyolites... Both the nature and composition of this rhyolite are obscured by strong hypogene and supergene alteration. Kistner (1984) reported unaltered rhyolite at Red Mountain that consists of porphyritic lavas and tuffs with K-feldspar and clinopyroxene phenocrysts in a fine matrix of devitrified glass and microlites. The unaltered equivalent of the Red Mountain rhyolite is the Gringo Gulch Volcanics, which consist of several hundred feet of intermediate to silicic (rhyolite to dacite) tuff, lava and volcanoclastic rock (Drewes, 1972; Simons, 1974)." (pg. 82-83)

PEKrf – Rhyolite of Red Mountain (lower?) (Cretaceous)
A subdivision of the rhyolite of Red Mountain covering a restricted area east of Red Mountain. Designated "Tfg" on the original map, with no further explanation available. It is included with PeKr because other geologic maps include it within the Rhyolite of Red Mountain.

Ka – Trachyandesite (Cretaceous)
Trachyandesite flows. Designated “Ta” on the original map. The following description is taken from Lecumberri-Sanchez et al. (2013, J. of Geochemical Exploration). “[A]ndesitic flows with minor tuff and shale interbeds that correlates with the trachyandesite of Meadow Valley (Simons, 1972). The flows are well exposed south, east, and north of Red Mountain over an area of ~10–12 mi^2 (25–30 km^2). The thickness of this andesite unit varies from a few to ~2000–3000 ft, the variable thickness reflecting irregular topography on the underlying rocks. Individual flows are a few tens of feet thick in the more northern and eastern exposures, but reach thicknesses of 300–400 ft in the southwestern portion of the unit, near the base (Simons, 1972). The andesite at Red Mountain consists of porphyritic lava with millimeter-sized plagioclase and augite phenocrysts. The matrix consists of plagioclase, interstitial feldspar and fine-grained hematite with volcanic glass locally (Kistner, 1984). The trachyandesite of Meadow Valley (with which the andesite at Red Mountain correlates; Simons, 1972) is texturally and compositionally variable and includes: thin lava flows varying from units containing augite- and andesine phenocrysts in a matrix composed of plagioclase microlites and glass, to more silicic porphyritic biotite-bearing lavas; coarse-grained, thick lava flows with plagioclase and pyroxene phenocrysts; and chloritic tuffs and shales (Drewes, 1972). Simons (1972) obtained a K-Ar date on biotite from one of the interbedded tuff units of 72.1 ± 3 Ma.”

Kv – Silicic-intermediate volcanic rocks (Cretaceous)
Silicic-intermediate lava flows with interbedded sedimentary rocks. Designated “Tl” on the original map. The following description is taken from Lecumberri-Sanchez et al. (2013, J. of Geochemical Exploration). “[A] suite of felsic volcanic units, with interbedded siltstone and conglomerate beds, underlies the andesite and is exposed on the southwest flank of Red Mountain. Simons (1974) estimates the exposed thickness at 1500 ft, but deep drilling suggests a thickness in excess of 3000 ft (Corn, 1975). Simons (1974) mapped an extrusive latite dome emplaced along the contact between the felsic volcanic rocks and the overlying andesite. Attitudes in these felsic units are generally concordant with or somewhat steeper than in the overlying andesite. The felsic volcanic rocks strike towards the southeast and may be part of a similar suite exposed 3 mi (5 km) to the southeast of Red Mountain and which hosts silver–manganese mineralization at the Hardshell deposit. The felsic volcanic rocks at Hardshell vary from volcanic conglomerate, tuffaceous sandstone and siltstone, silicic to intermediate tuff, welded tuff and lava (Drewes, 1972) and lie disconformably on a 4400 ft section of Paleozoic sedimentary rocks, mostly limestone and dolomite.”

Kvf – Silicic-intermediate (felsite?) volcanic rocks (Cretaceous)
Designated “Tf” on the original map. While this unit is distinguished on this map, it is included with the lower volcanic unit (Kv) on all other available maps. “Tf” may indicate a Tertiary felsite.

Final Datasets and Products

Original Documents

All scanned original documents are available through the University of Arizona Campus Repository and the Arizona Geological Survey Document Repositories. The original drilling data logs are grouped by drill hole in the University of Arizona Campus Repository and include several different document types which we describe below.

Kerr-McGee Summary Logs
Brief logs summarizing lithology and alteration/mineralization observations for select drill holes. Drill holes ranging from DDH-001 to DDH-122 have logs in this style.

Kerr-McGee Simple Logs
Simple geologic logs including assays and descriptions. These are all named “DDH-###_KerrMcGeeSimple”. Drill holes ranging from DDH-113 to DDH-146 have logs in this style.

Kerr-McGee Detailed Logs
Detailed logs that include quantitative and qualitative information on alteration, mineralization, lighology, and vein mineralogy, as well as assay. These documents are all named “DDH-###_KerrMcGeeDetailed”.

These logs suffered more water damage and deterioration than any of the other groups of documents. Drill holes ranging from DDH-146 to DDH-167 have logs in this style. Note, DDH-146 has a single document with part of the hole logged in the “simple” format and part in the “detailed” format.

Cominco Logs

Drill logs made by Cominco include quantitative and qualitative information on alteration, mineralization, lighology, and vein mineralogy, as well as assay data. They also produced graphical representations of the core on these logs which are not captured in our tabulated data. These documents are all named “DDH-###_CominсoLog”. Select drill holes ranging from DDH-105 to DDH-153 have logs in this style.

Composited Assays and Mineralogy Data

These Kerr-McGee documents include assay data (Cu, Au, Ag, Pb and Zn) for select drill holes, as well as quantitative mineral proportions. All are named “DDH-###_Assay”.

Kerr-McGee Assay Graphs with Comments

A series of hand plotted graphs of down hole assays with minimal notes on lithology, alteration and other items. None of the data on these documents was digitized.

Other Documents

A zip file containing other miscellaneous documents is also included. Two are geologic cross sections through parts of the Red Mountain porphyry system. One is a “Prospectus” written by R. Roe at an unknown date. Two are memoranda between R. Roe and Steve Richard (AZGS) regarding the donation of these drilling documents to AZGS.

Tabulated Data

The newly tabulated drilling data are contained in five spreadsheets, with separate files for simple and detailed Kerr-McGee logs, Cominco logs, Assay data, and downhole survey data. Data from simple and summary Kerr-McGee logs were compiled together in “RedMountainAZ_Kerr-McGee_Simple.xlsx”. New whole rock geochemical data is also available as a separate file.

Geospatial Data

A series of items containing geospatial data is made available with this report. These include the following. 1) A GeMS-complaint ESRI Geodatabase containing feature classes for map unit polygons, contacts and faults, orientation points, and drill hole locations (stations), as well as other required tables. 2) A PDF map layout containing the full digitized geologic map with explanations. 3) An ESRI ArcPro layer package that contains all the GIS data with the symbology used in the map layout. 4) A KMZ of the digitized geologic map. 5) A zip file containing five georeferenced maps. 6) A zip file containing a shapefile with the digitized downhole survey points.

Webmap

The digitized geologic map is also freely available as a web-based format (https://arcg.is/1fSamP2), with which users can examine the geologic data and link to the original drill log scans from the drill hole locations.

Future Work

The Arizona Geological Survey is actively working on the Red Mountain porphyry Cu-Mo system as part of a USGS-funded project on the critical mineral potential for porphyry Cu systems. The deep holes provide fantastic exposures of vertical zoning through a porphyry system, with the more distal holes providing the lateral exposures up to ~3 km in either direction. We hope to release the initial results of that work in late 2025/early 2026.

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