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OM 145

Geo of Kaibito &

Moenkopi Plateaus

filed F2A2

COPPER PROSPECT

WHITE MESA MINING DISTRICT

COCONINO COUNTY ARIZONA

R. L. Sielaff
September, 1970

2000 Cherryville Road
Littleton, Colorado 80121
Phone: 761-0715

file White Mesa project

March 31, 1971

Mr. Joe Walton, President
Nuclear Dynamics
2871 Sky Harber Blvd.
Phoenix, Arizona 85036

Dear Mr. Walton:

This letter will confirm our discussions in your offices last week.

I presented a copper-uranium play in the White Mesa area in Coconino County, Arizona.

The play involves exploration bidding by sealed bid at the Navajo sale and drilling, testing the Navajo Shinarump and Coconino sands.

I am not asking for any front money, but am asking a 2% royalty on net smelter returns. This is subject to negotiation and if the deal is acceptable geologically I am sure we can work out terms mutually acceptable.

Yours truly,

R. L. Sielaff
2000 Cherryville Rd.
Littleton, Colo. 80120

RLS mw

ABSTRACT

The White Mesa Mining District lies in the Navajo Indian Reservation in Coconino County Arizona. Copper ore has been mined in the past consisting of mostly malachite and copper silicates with minor sulphides from the Navajo sandstone of lower Jurassic age.

The deposits are thought to be epigenetic entering the Navajo through fractures from an unknown source below.

Approximately 2.25 million tons of ore averaging about 1% Cu are indicated in ore bodies that are exposed or penetrated by drill holes. In addition, 14 million tons is inferred by the U.S.G.S.

Several attempts to mine copper from the Navajo sand have failed in the past. This report proposes that a major deposit of primary sulphides could exist in the Shinarump and Coconino sands at depths of 2,500 and 3,220. Along with the copper it is also possible to have accumulations of uranium.

OBJECTIVE OF PROSPECT

This report proposes that the Shinarump and Coconino sandstones could be a host for a high grade large primary copper sulphide deposit. It is evident that copper charged solutions rose from a deeper source along fault zones and fracture systems to deposit copper ores in the Navajo sandstone. It is believed that these copper bearing solutions first entered porous sandstones in the subsurface depositing

sulphide ores filling up most of the pore space in these sands in the area of the fault pattern in the Mormon Ridges and the old mining district. When the porosity was filled by ore, the solutions then rose further finally settling in the Navajo. If there is this much copper in the Navajo, it is not unreasonable to assume that a major deposit could be expected in the Shinarump and Coconino which have a known affinity for copper throughout the entire area.

PROPOSED EXPLORATION PROGRAM

Phase I: Color air photos should be purchased and interpreted to delineate fault and fracture patterns. They should also be used to define green and blue copper surface coloration. Outline is shown on Plate I.

Phase I cost for 9 Townships $4,300.00

Phase II: This phase covers bidding on tracts at a sale not yet announced by the Navajo Tribe. It also will include obtaining deals from inactive companies or individuals who have existing leases in areas determined to be favorable by Phase I.

It is believed that a bid of $10 to $20 per acre on 2,500 acre tracts would be competitive with a high bid on the tract most favorable from Phase I.

A proposed plan might be as follows:

5 tracts of 2560 acres each at $2.10 =	$ 26,880.00
1 tract of 2560 at $10.42/acre	26,664.20
1 tract of 2560 at $20.61/acre	52,761.60
	$106,305.80

Phase III

A drilling program would, of course, depend on the amount of acreage acquired. An initial program would be to drill in areas of high fracturing and faulting arranged to fit the structures on 1,000 foot centers.

Cost of air drilling to 3,300 feet to test Coconino would be $6.00 to $7.00 per foot and coring $30.00 to $40.00 per foot. Using averages, costs are as follows:

Drilling 3,100 feet at $6.50	$20,150.00
Coring 200 feet at $35.00	7,000.00
	$27,150.00

A minimum 4 well exploratory drilling program would cost $108,600.00. Development drilling would depend on results of this drilling.

HISTORY OF AREA

The copper occurrences in the White Mesa area have been known for a long time. The first prospectors were the Navajos who were looking for turquoise and had located this green blue ore. The first known white men in the area were Thomas V. Keams and party in 1882 who recorded 35 claims. Since then there have been many unsuccessful attempts to exploit the shallow deposits. The Navajo Copper Company made an unsuccessful attempt in 1917-18 and the Coconino Copper and Chemical Company operated from 1939-40. In 1941 the Maedun Company was formed to develop a large tonnage of low grade ore using a dry concentration process.

Shattuck-Denn Mining Company conducted an extensive drilling and exploration program of the Old Fort Hill area in 1942. Coronado Copper and Zinc Company obtained an

option on the Mardun lease in 1943.

The U.S.G.S. made an extensive survey of the area and the report was released to open file on October 28, 1943. The White Mesa Mining Company has since done work, but nothing is known of the results.

All of the drilling done was in the Navajo sands and limited to very shallow depths.

GEOGRAPHY

The White Mesa District lies in unsurveyed land of T37N-R9 and 10E, in Coconino County Arizona in the Navajo Indian Reservation, at an elevation of 6,000 feet. Local relief is about 420 feet. It is 112 miles northeast of Flagstaff, the nearest rail point, and about 26 miles north of the Gap, a small settlement on U.S. Highway 89. A dirt road leaves the Gap and goes through the district coming out at Gage.

Rainfall is under 10 inches and the Navajo sand is dry in the immediate area.

The district lies on the Kaibito Plateau on the Mormon Ridges.

The Echo Cliffs lie 10 miles west.

STRATIGRAPHY

The stratigraphy and geologic column are described and shown in Oil and Gas investigation map OM 145 (2 sheets), enclosed with this report.

Section C shown on Sheet 2 at Tanners Well is the closest to the district, and depths and thicknesses are listed as follows:

	Top	Thickness
Navajo Sandstone	0	1300
Kayenta	1300	400
Wingate	1700	300
Chinle	2000	500
Shinarump	2500	150
Moenkop	2650	400
Kaibab	3050	300
Toroweap	3170	120
Coconino	3220	50

STRUCTURE

The White Mesa mining district lies on the Kaibito Plateau in an area of flat to gently dipping Navajo sandstone. The north-south trending Echo Cliffs monocline lies 10 miles to the west.

The Preston Mesa anticline, trending northwest, runs through the area of the Indian leases being put up for sale. The Tuba City syncline lies approximately 6 miles west of, and generally paralleling, the Preston Mesa Anticline. The old mining activity in the district occurred between the two structural features.

The principal area of interest is in the old mining district around the Copper Mine Trading Post and in the faulted area in the Mormon Ridges which is all in the same general structural province. In this area a number of faults have been mapped trending approximately N20°W with high angle. They vary with some "up" on the east and some on the west side. Several faults branch off of these and trend in a northeasterly direction. (See Plate I, Sheet I).

Faults are characterized by reefs of silicified breccia and gauge. Chalcedony and rarely calcite are found in the fault zones.

In the old mining district a set of master joints trending northeast intersect the northwest trending faults to form a complex fracture pattern favorable to mineralization. It is probable that the same situation exists throughout the Mormon Ridge.

COPPER DEPOSITS IN NAVAJO SANDSTONE

Copper ore is principally malachite with associated chrysocolla. These minerals are disseminated through the sandstone, partially filling pore space, form coatings on grains, and occasionally occur as veinlets. Chalcocite and bornite are present, but in minor amounts. Chalcedony occurs in stringers and is associated with the higher grades of ore.

The known ore bodies are mainly around the area of the Copper Mine Trading Post.

The Little Dick, Grand Pacific, Copper World, and California are large, low grade, tabular bodies where weak mineralization occurs in large bodies locally exceeding 80 feet in thickness. Closely spaced small bodies occur on the Dutchman claim, and in the area of the Coronado lease on and near Copper Hill and Old Fort Hill. On the Queen claims a large, but very low grade, body is exposed and smaller ones occur on the Sunset and Roy claims.

The majority of copper deposits, according to C. B. Read (1943), are associated with joints, but relatively few are adjacent to fault zones. They are epigenetic and are

products of precipitation from dilute copper bearing solutions which entered the Navajo sandstone along fissures and spread along permeable laminae away from these fractures.

The original sulphide deposits have undoubtedly been modified by downward moving surface waters and probably rich concentrations of ore have been oxidized and disseminated into widespread low grade deposits.

ORE GRADES

Various grades have been reported by different authors.

Wells (1905) from 18 claims reported copper varying from 0.3 to 23.4% and silver from 0 to 8.3 oz. per ton. A composite of these assayed a trace of gold, 2.6 oz. silver per ton and 2.4% copper.

In 1940 the Coconino Copper and Chemical milled ore running 3.13% copper, however, this ore must have been carefully selected. Mitcham (1942) cut 96 samples that averaged 0.001 oz. gold, 0.24 oz. silver, and 0.87% copper.

It is believed that this deposit has been disseminated to a wide extent. Primary sulphides in the Shinarump and Coconino along and out from the faults and fracture zones could be extremely rich.

RESERVES IN THE NAVAJO SANDSTONE

The following reserves are taken from a U.S.G.S. open file report of C. B. Read, et al, (1943). Indicated ore is in the known ore bodies and inferred ore is possible reserves

that may exist in concealed ore bodies. In the U.S.G.S. report inferred ore includes only those possible reserves which may be present, although not exposed in undissected mesas and buttes. Estimates of this class of reserves have been calculated by applying the ratio of volumes of sediments to volumes of ore as measured in adjacent outcrops. They are not in any sense accurate estimates, but they do provide a reasonable indication of the general order of magnitude of completely hidden and still undiscovered reserves.

TABULATION OF ORE RESERVES

WHITE MESA MINING DISTRICT

Indicated Ore

	Reasonably Assured	In Probable extensions	Totals
Grading 1 to 4% (in scattered small bodies).	80,000	180,000	260,000 tons
Grading 0.3 to 1% Cu (in a few large and many small bodies).	535,000	1,465,000	2,000,000 tons
	615,000	1,645,000	2,260,000 tons

Inferred Ore

	In concealed orebodies	
In area west of Eastern Star fault	7,250,000	
In area east of Eastern Star fault	6,750,000	
	14,000,000	14,000,000 tons

TOTAL INDICATED AND INFERRED RESERVES..... 16,260,000 tons

LAND STATUS

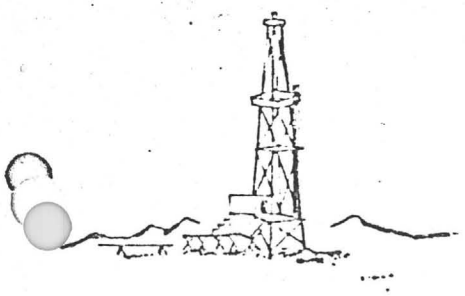
All of the area involved is on the Navajo reservation. The status of the old leases is not known.

The proposed color air photo survey might indicate what blocks would be of interest and an attempt should be made to get these leases.

It is my understanding that a copper lease sale will be held at Window Rock, Arizona, with sealed bids.

It has been approved by the Indians, but has not been announced. It is to carry a 5% override on copper and the outline of the lands is shown on Plate I.

If uranium is found associated with the copper, a lease can probably be negotiated with the Tribe. They have their own royalty schedule which would probably apply, a copy of which is included in this report.



THE NAVAJO TRIBE

MINERALS DEPARTMENT
P.O. BOX 146
WINDOW ROCK, ARIZONA
86515
PHONE: 602 - 871 - 4171

September 18, 1970

Mr. R.L.Sielaff
2000 Cherryville Road
Littleton, Colorado 80120

Dear Mr. Sielaff:

It was most enjoyable meeting you and having an opportunity to talk about copper.

Some of the individuals who appear to be involved in the claims under litigation are:

R.L.Olliver & Associates
757 Lincoln Building
Spokane, Washington

Donald J. Ames
Box 202
Fargo, North Dakota
or
Box 1565
Page, Arizona

Jack W. Taitch
4118 S. Pittsburg
Spokane, Washington 99203

Your question regarding minerals such as uranium which might be encountered while seeking copper, for example, can be answered. In this situation the lessee can enter into negotiations with the Tribe for a lease. This would also include royalty and other pertinent matters. As the Tribe has their own royalty for uranium obviously it would apply.

We hope you can visit with us again in Window Rock.

Most sincerely,

Perry K. Hurlbut
Minerals Supervisor

MINERALS DEPARTMENT
THE NAVAJO TRIBE
BOX 146
WINDOW ROCK, ARIZONA
86515

RECENTLY YOU WERE SENT A COPY OF THE NEW APPROVED NAVAJO URANIUM ROYALTY SCHEDULE. TO ASSIST YOU IN DETERMINING THE ROYALTY PER TON UNDER THE NAVAJO SCHEDULE, THE FOLLOWING DATA ARE PRESENTED:

ROYALTY PER TON

ORE GRADE	$7.00 U_3O_8	$8.00 U_3O_8	$9.00 U_3O_8
.15	$0.94	$1.08	$1.23
.20	1.86	2.16	2.48
.25	2.52	2.94	3.38
.30	3.22	3.78	4.36
.35	3.97	4.67	5.42
.40	4.76	5.62	6.53
.45	5.59	6.63	7.73

EXHIBIT "A"

NAVAJO URANIUM ROYALTY SCHEDULE

ROYALTY: To pay or cause to be paid to the Area Director, Navajo Area, Window Rock, Arizona, for the use and benefit of the Lessor, a royalty, calculated on a monthly weighted average on the basis of dry short tons of ore mined and delivered to a treatment plant.

1. (a) For Uranium

Lessee shall pay to the Lessor a percentage royalty of the value per dry ton based on royalty rates of 12 percent for ore valued at $0.01 per ton and increasing to 25 percent for ore valued at $100.00 or more per ton. The royalty rate shall be determined to the nearest 0.00 percent in accordance with the following formula:

$$\text{Percentage Royalty Rate} = 12\% + 0.13\% \left(\frac{\text{Value per dry ton}}{\$1.00}\right)$$

(b) "Value per dry ton" wherever used in this paragraph is hereby defined as the dollar value per dry ton (2,000 pounds) of crude ore, as determined by application to the uranium content of such ore of the following "Value Schedule for Uranium Ores", multiplied by a fraction whose numerator is the weighted average price per pound for U_3O_8 in uranium concentrate received by the Lessee, or the seller of Lessee's concentrate, at the mill processing ores derived from the leased lands, during the month for which royalty is being computed and whose denominator is $7.25, except that if no sales have been made during the month for which royalty is being computed, then the numerator shall be the weighted average price per pound of U_3O_8 received by the Lessee or the seller of Lessee's concentrate during the preceding six (6) months.

VALUE SCHEDULE FOR URANIUM ORES

U_3O_8 Assay of Ore	Value per pound of U_3O_8 Contained in Ore
0.10 percent or less	$1.50
0.11	1.70
0.12	1.90
0.13	2.10
0.14	2.30
0.15	2.50
0.16	2.70
0.17	2.90
0.18	3.10
0.19	3.30
0.20 and more	3.50

plus a grade premium of $0.75 per pound for each pound of U_3O_8 in excess of four (4) pounds per ton of ore and an additional premium

of $0.25 per pound for each pound in excess of ten (10) pounds U_3O_8 per ton of ore. Fractional parts of a pound to be valued on a pro rata basis to the nearest cent.

(c) Whenever vanadium and other minerals associated with uranium are recovered and sold by Lessee, Lessee shall pay to Lessor a royalty of ten (10) percent of the gross proceeds derived from such sale; and where the Lessee retains possession of the associated mineral products a separate royalty value will be negotiated.

(d) Lessee agrees to pay to the Lessor a royalty of ten (10) percent of the value of uranium recovered from mine waters (whether natural or introduced), from leaching ores in place on the leased lands or by leaching such materials after they have been mined or extracted from the leased lands, or by leaching the waste material resulting from the treatment of ores from the leased lands. The value of uranium, as used herein, shall be the weighted average price per pound for U_3O_8 in uranium concentrate received by the Lessee, or the seller of Lessee's concentrate, at the processing plant producing such concentrate, during the month for which royalty is being computed, except that if no sales have been made during the month for which royalty is being computed, then the value of uranium shall be the weighted average price per pound of U_3O_8 received by the Lessee or the seller of Lessee's concentrate during the preceding six (6) months.

EXAMPLES OF ROYALTY CALCULATIONS

The following formula will be used in calculating a "Percentage Royalty Rate" (PRR) for uranium:

$$PRR = 12\% + 0.13\% \left(\frac{\text{Value/dry ton}}{\$1.00} \right)$$

This formula was developed using the A.E.C. Circular 5 values, a royalty rate spread from 12% to 25% for ore values from $0.01 to $100.00 or more per ton, a concentrate value factor, and no deduction for haulage.

The factor of 0.13 used in the formula is derived from the relation of the royalty rate spread of 12% to 25% and the ore value of $00.01 to $100.00.

$$\frac{12\% \text{ to } 25\%}{\$0.01 \text{ to } \$100.00} = \frac{13 \text{ units}}{100 \text{ units}} = 0.13$$

"Value per dry ton" as used in the PRR formula is the value per ton of ore as determined from the A.E.C. value schedule multiplied by a concentrate factor.

The numerator in the concentrate factor is the average price for U_3O_8 in uranium concentrate received by the Lessee during the month for which royalty is being computed and whose denominator is $7.25, except that if no sales have been made during the month for which royalty is being computed, then the numerator shall be the weighted average price per pound of U_3O_8 received by the Lessee or the seller of Lessee's concentrate during the preceding six (6) months.

EXAMPLE 1

Assume: 0.19% U_3O_8 in ore; concentrate factor, whose numerator is $8.15 per pound, will be $8.15 divided by $7.25 = 1.1241

Value/dry ton for use in the PRR formula is:

2000 lbs. x 0.19% = 3.8 lbs.

3.8 lbs. x $3.30 (Price from AEC Value Schedule) = $12.54

$12.54 (Value/dry ton) x 1.1241 (concentrate factor)=$14.10

Example 1 (continued)

PRR $= 12\% + .13\% \left(\frac{\text{Value/dry ton}}{\$1.00}\right)$

$= 12\% + .13\% \left(\frac{\$14.10}{\$1.00}\right)$

$= 12\% + .0183$

$= 12\% + 1.83\% = 13.83\%$

Royalty/ton = PRR x Value/dry ton

= 13.83% x $14.10

= .1383 x $14.10

= $1.95

EXAMPLE 2

Assume: 0.24% U_3O_8; concentrate factor, whose numerator is $6.25 per pound, will be $\frac{\$6.25}{\$7.25} = .8621$

Value/dry ton for use in the PRR formula is:

2000 lbs. x 0.24% = 4.8 lbs.

4.8 lbs. x $3.50 (Price from AEC Value Schedule) + [0.8 lbs. x $0.75 (Price from AEC Value Schedule) in excess of 4 lbs.] = $16.80 + $0.60 = $17.40

$17.40 x .8621 (concentrate factor) = $15.00

PRR $= 12\% + .13\% \left(\frac{\text{Value/dry ton}}{\$1.00}\right)$

$= 12\% + .13\% \left(\frac{\$15.00}{\$1.00}\right)$

$= 12\% + .0195$

$= 12\% + 1.95\%$

$= 13.95\%$

Royalty/ton = PRR x Value/dry ton

= 13.95% x $15.00

= .1395 x $15.00

= $2.09

This Report contains as appendix the following:

USGS Open File Report, Copper Deposits of the White Mesa Mining District, Coconino County, Arizona, by Read et.al., August 1943, (available at Salt Lake City).

Kiersch, George A., Mineral Resources of Navajo Hopi Indian Reservations, Arizona-Utah, Vol. 1, Metalliferous Minerals and Mineral Fuels, prepared by U. of A. 1955

OM 145 Geology of the Kaibito and Moenkopi Plateaus and Parts of the Painted Desert, Coconino County, Arizona, 1953 (2 sheets)

Sheet 1 of PP 521-A, Geology Map of Navajo and Hopi Indian Reservations 1969

(cont.)

Copper Deposits of the White Mesa Mining District, Coconino County, Arizona.

by

Charles B. Read
R. D. Sample
H. H. Sullwold, Jr.

Open Files, Salt Lake City

United States Department of the Interior
Geological Survey

August, 1943.

Maps folded in separate folder attached.

DEPARTMENT OF THE INTERIOR

INFORMATION SERVICE

GEOLOGICAL SURVEY

For Release OCTOBER 28, 1943.

COPPER DEPOSITS OF THE WHITE MESA MINING DISTRICT,
COCONINO COUNTY, ARIZONA

A study of the copper deposits of the White Mesa mining district, Coconino County, Ariz., has recently been completed by C. B. Read, R. D. Sample, and H. H. Sullwold, Jr., of the Geological Survey, United States Department of the Interior. This work was a part of the Survey's program of providing geologic information to aid in developing known deposits of minerals needed for war purposes and to guide the search for new deposits.

The report and maps based on this work are available for public inspection in open files at the offices of the Geological Survey in Washington, D. C., and in Salt Lake City, Utah.

P. I. 20259

CONTENTS

ILLUSTRATIONS

Copper Deposits of the White Mesa Mining District, Coconino County, Arizona.

Summary. The White Mesa Copper Mining District is an area of approximately 10.5 square miles near the western margin of the Kaibito Plateau in unsurveyed T 37 N, Rs 9 and 10 E, Coconino County, Arizona. It is 112 miles northeast of Flagstaff, Arizona, the nearest rail head, from which it is accessible by paved and secondary road, and is at an elevation of about 6400 feet. Inadequate water supply and isolation from supply centers and smelters are factors which have inhibited development and which may be expected to handicap mining operations in the district.

Sporadic attempts to develop the reserves of the district have been unsuccessful, and production has been minor. At present, three companies are interested in development, and are engaged in, or have recently attempted, prospecting.

The copper deposits occur in the upper portion of the nearly horizontal, highly crossbedded, gray Navajo sandstone (Jurassic ?). Occasional large tabular bodies and numerous small pods of copper ore occur through an interval of at least 150 feet in the upper part of the formation. The deposits are disseminations of malachite, copper silicates, and minor quantities of copper pitch and sulfides in sandstone, the copper minerals serving as cementing and grain-coating materials. Grade varies up to 15% copper but it is doubtful if many of the deposits will average much higher than 1%. The larger bodies, some of which contain several hundreds of thousands of tons, may be expected to average less than 1%. The deposits show a well-defined fissure control. Origin may have been telethermal or meteoric, but there is no decisive evidence bearing on this point.

The mineralization is too sporadic to permit accurate estimation of ore reserves in the absence of extensive underground exploration or mining operations. The following preliminary figures are therefore only indicative of the general magnitude of the deposits. Approximately 2,250,000 tons of ore averaging about 1% Cu are indicated in ore bodies that are exposed or penetrated by drill holes. Only a few thousand tons of this total can be classed as "measured ore" on the basis of available data, but 615,000 tons are reasonably assured. The remaining 1,650,000 tons probably exist in extensions, indicated by geologic evidence, of the known ore bodies. In addition, 14,000,000 tons is the inferred order of magnitude of an aggregate tonnage of mineralized sandstone that may exist in "blind" ore bodies concealed in undissected uplands.

Consideration of the average grade and size of the known deposits suggests that large-scale development of these reserves under present conditions will be a marginal enterprise, even under favorable operating conditions. The additional problems imposed by inadequate transportation facilities and water supply enforce a pessimistic outlook. The relatively large inferred reserve of concealed ore cannot be regarded as a mitigating factor because it is problematical whether concealed ore bodies can be discovered and developed at reasonable costs.

It is recommended that further attempts to prospect or to develop the copper reserves of the district be prefaced by a careful analysis of mining and concentrating costs based on minimum tonnage estimates. Only in the event that such a survey indicates economic feasibility, should additional steps in development be undertaken.

Introduction

The sandstone copper deposits here described are near the northwestern margin of the Kaibito Plateau in the western Navajo Reservation, Coconino County, Arizona. The area, known as the White Mesa Mining District, is in unsurveyed T. 37 N., Rs. 9 and 10 E. It consists of 9 patented and 28 unpatented claims, two mining and prospecting leases, an abandoned millsite lease, and a campsite lease. Sporadic attempts to mine the small deposits of high grade ore in the district have been futile. Recently, comprehensive prospecting programs by three companies have been initiated in a determined effort to ascertain the feasibility of developing, on a large scale, the low-grade copper reserves in the district.

The area of approximately 10.5 square miles which encompasses the claims and leases is about 112 miles northeast of Flagstaff, Arizona, from which it is accessible by U. S. Highway 89 to Gap Trading Post, and from there by dirt road twenty-six miles to the Copper Mine Trading Post in the northwestern portion of the district. The mean altitude is about

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/ In the southwestern part of the area some maps show two additional claims, the corners of which were not found in the field.

6,400 feet, and the local relief is approximately 420 feet. Annual precipitation is less than 10 inches, and surface and ground water are scarce in and adjacent to the district. This deficiency of water, isolation from supply centers, and lack of adequate transportation routes are important factors which have inhibited development of reserves in the district.

Only one report bearing on the geology of the White Mesa Mining District has been published, a brief and general account by J. M. Hill.[1] However, a number of confidential reports have been prepared by geologists and engineers employed by companies interested in the area, and several of these have been examined during the course of the recent Geological Survey investigations. Company prospecting data have likewise been consulted freely, and grateful acknowledgment of the courtesies of the Shattuck-Denn, Coronado, and Mardun organizations in making these available, is here expressed.

Field work by the Geological Survey was begun late in March and was completed early in July, 1943. The investigation was part of a program designed to determine the status of marginal copper deposits and was undertaken by the Geological Survey at the request of the War Production Board. C. B. Read was in charge of the White Mesa project, and was assisted by H. H. Sullwold during the entire period of study. R. D. Sample joined the party on May 23, and aided in the later stages of the work.

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[1] Hill, J. M. Copper deposits of the White Mesa district, Arizona; U. S. Geol. Survey. Bull. 540, pp. 159-163, 1914.

Development and Production

Mining operations in the White Mesa District were first attempted by Mormon settlers who, in the latter part of the past century, located the mining claims and opened many of the known copper bodies. An unknown, but relatively small tonnage of high-grade ore was recovered during this early period of discovery and initial development.

In 1917 operations on the Little Dick and Copper World claims were attempted by the Navajo Copper Company. Two open cuts were developed, and 290,000 pounds of copper, as well as a small quantity of silver, are reported to have been recovered. The operations were not profitable, and were discontinued in 1918.

The Coconino Copper and Chemical Company began operations in the western part of the district in 1939 and suspended them in 1940. Their activities were mainly on the Copper World and Dutchman Claims. Complete records of production are not available. However, in 1940 they treated 4,584 tons of 3.13% ore from which 797,878 pounds of copper sulfate were produced and shipped.

The Mardun Company, which was formed in 1941, milled 3000-3500 tons of ore which yielded about 150 tons of concentrates estimated to contain from 15 to 20 percent copper. This company operated on a mining lease obtained from the Navajo Indian Service. In 1943 an option on the Mardun lease was acquired by the Coronado Copper and Zinc Company. An intensive prospecting program begun by the Mardun organization has been continued in an effort to locate large low-grade ore bodies on the property. It is reported that the Mardun Company drilled 17,000 feet of test holes with an average depth of 24 feet or less. Records of a number of these have been examined, but others are lost. Known locations are shown on the map, Plate II B.

The recent activities of the Coronado Company suggest that the assay logs of these tests show unduly high copper content. In order to avoid confusion the data are therefore witheld until the matter is clarified by shaft-sinking and drilling now in progress. At present the engineers of the organization are pessimistic regarding the possibility of discovering large orebodies on the lease.

In 1926 the Shattuck-Denn Mining Corporation acquired tax titles on the nine patented claims in the White Mesa District. More recently they obtained options on the unpatented claims and in 1942 undertook a drilling and prospecting program in Old Fort Hill area. About 4700 feet of core holes were drilled and assayed. Locations of these holes and summaries of mineralized sandstone encountered are shown on the map, Plate II.

Geology

Most of the Kaibito Plateau, in the area studied, is surfaced by nearly horizontal, highly crossbedded, gray Navajo sandstone of Jurassic(?) age. About 1525 feet of clastic sediments assigned to this unit were measured in an incomplete section at Echo Cliffs immediately west of the district where the Navajo is underlain by Triassic clastic sediments and Permian limestone. To the east, red clastic sediments assigned to the Carmel formation rest on the Navajo.

The major structural feature of the western Kaibito Plateau is Echo Cliffs monocline which trends north-northwest to north along the margin of the table land. The steep dips on this flexure flatten gradually eastward into the plateau, but the regional dip continues east to southeast. Oblique normal faults locally complicate the Echo Cliffs monocline and extend northeastward into the plateau, where they are difficult to trace because of the

homogenous nature of the Navajo sandstone which forms both walls at the surface.

Geologic features of the White Mesa District.- The White Mesa Mining District occupies an area some 10 miles east of the Echo Cliffs monocline. Nearly horizontal Navajo sandstone, overlain by a veneer of dune sand, is the surface rock throughout the district. Approximately 420 feet of the unit, constituting the upper portion of the formation, are exposed in the area.

The fracture pattern of the White Mesa District is shown in Plates I and II. Fault fissures trend north-northwest and east-southeast in the western part of the district. Most of these show a slip down to the west or northwest. Sheeted zones traversed by parallel to subparallel faults and joints are marginal to the major fissures. A set of master joints, trending northeast, intersects these fractures, forming a complex system. In the central and eastern portion of the district northeast-trending master joints constitute the dominant fissures. Reefs of silicified breccia and gouge characterize the faults. Veinlets of chalcedony and, more rarely, calcite occur in the fault zones and walls. The major joints also commonly show extensive silicification.

Mineral Deposits.

The copper deposits of the White Mesa district vary from large low-grade tabular bodies to small irregular pods and veins ofhigher grade ore. Most of the well-exposed bodies are along or near zones of south, southeast, or northeast-trending joint or fault fissures which constitute the dominant structural control of ore deposition. The deposits have a very limited vertical extent and few show thicknesses which exceed 50 feet. The majority are similarly limited horizontally. Grade varies widely but is predominantly low, and for the district as a whole will not exceed 1%. Inferred reserves of this low-grade

ore are large, but the cost of exploring the deposits will probably be high due to the large area which must be prospected.

Mineralogy.--Malachite is the most important copper mineral in the district and is usually associated with "chrysocolla."/ These two minerals are disseminated through the sandstone in which they partially fill pore spaces, form coatings on grains, and occasionally occur as veinlets.

Copper pitch occurs in the wall rock of fissures where it frequently forms a halo around disseminations of chalcocite or bornite. The small quantity of both oxides and sulfides make their economic consideration negligible.

Gangue, in addition to sand grains comprising the sandstone, is mainly chalcedony which occurs in anastomosing stringers associated with the higher grades of ore. Veinlets of calcite are rare. Limonite is commonly disseminated in the sandstone as variable but rarely extensive halos around the copper bodies.

Distribution.—Large, low-grade copper deposits are mainly restricted to the northwestern portion of the district in the area between the Ida M. Smyth and Eastern Star faults. The most notable of these are the Little Dick and its possible Grand Pacific extension, the Copper World, and the California deposits. Series of closely spaced small bodies occur on the Dutchman claim, and in the area of the Coronado lease on

/ The exact composition of the copper silicates has not been determined. Clays, which are the common cementing minerals in the Navajo sandstone, have been combined with soluble copper compounds forming copper carbonate disseminated in clay, silicates, and oxides, Cf. Clark, F. W., The data of Geochemistry: U. S. Geol. Survey Bull. 770, pp. 670-680, 1924.

and near Copper Hill and Old Fort Hill. A rather large, but very low grade, body is exposed on the Queen Claim, and smaller ones occur on the Sunset and Ray Claims.

Throughout the district there are numerous small copper bodies. The distribution of the various exposed deposits and of their indicated or inferred extensions is shown on the map, Plate I.

Form and Character.—The copper deposits are very irregular and pockety. As indicated above, the larger, low-grade, tabular deposits are exemplified by the Little Dick, Grand Pacific, Copper World, and California bodies where weak mineralization occurs in large areas of sandstone. Drill-hole records show that these may exceed 80 feet in thickness. Such bodies are traversed by numerous joint fissures, the walls of which frequently show stronger mineralization than does the intervening sandstone. The small, higher grade bodies often occur as disseminations in the walls of fissures, and are usually vein or pod-like in character. Few have been observed to extend as continuous deposits for a greater horizontal distance than 50 feet. It is probable that their maximum vertical dimensions are approximately the same as those of the tabular bodies.

Control.—The majority of copper deposits examined are associated with joints, but relatively few are adjacent to fault fissures. In the western part of the district fissuring is dominantly south-southeast although locally it trends nearly east. Farther east most of the fissures associated with copper deposits are northeast-trending. Copper mineralization is commonly, although not invariably, strongest in the walls of the joint fissures but continues, with decreasing intensity,

for a variable distance away from the apparent feeders. Joints which are strongly silicified appear to have constituted partial barriers to copper-bearing solutions and to have caused the waters to spread widely along bedding planes.

The White Mesa copper deposits are epigenetic and are products of precipitation from dilute copper-bearing solutions which entered the Navajo sandstone along fissures and spread along permeable laminae away from these fractures. It is not clear, however, whether the solutions were meteoric or telethermal.

There has been some modification of the original form and composition of the copper deposits. Downward-moving surface waters have undoubtedly resulted in the oxidation of the copper sulfides which were probably important primary minerals in the deposits. Such waters have also caused rather wide dissemination of originally more restricted deposits as a result of leaching and reprecipitation. "Sweating" of the sandstone has apparently resulted in concentration of soluble copper minerals near the present topographic surfaces.

Reserves

The status of mining development in the White Mesa Mining District does not permit highly accurate estimates of copper reserves. The ensuing discussion is an attempt to indicate the general magnitude of these reserves and their approximate range in grade as determined in the course of surface mapping. Drilling and assay data are available only in the western part of the district and have been freely used to supplement outcrop data.

In terms of the classification of ore reserves recently adopted jointly by the Geological Survey and Bureau of Mines,[1] reserves of ore in the known ore bodies of the White Mesa district are herein classed as indicated ore, and possible reserves that may exist in concealed ore bodies are classed as inferred ore. A significant portion of the indicated ore, in parts of ore bodies bounded by very moderate extensions from observed faces of ore in open cuts, shallow shafts, or short adits, is reasonably assured. The remainder of ore in this class, although regarded with less assurance, is believed to exist in farther extensions of the ore bodies. Outlines of these blocks (Plates I and II) are based on geologic evidence with little or no prospecting control. If further refinements in classification were justified a small fraction of the indicated ore might be regarded as measured, and a similarly small fraction around the fringes of the assumed outlines might be regarded as inferred ore. In this report, however, inferred ore includes only those possible reserves which may be present, although not exposed, in undissected mesas and buttes. Estimates of this class of reserves have been calculated by applying the ratio of volumes of sediments to volumes of ore as measured in adjacent outcrops. They are not, in any sense, accurate estimates, but they do provide a reasonable indication of the general order of magnitude of completely hidden (and still undiscovered) reserves.

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[1] Eng. & Min. Jour., vol. 144, No. 6, p. 94, June 1943.

TABULATION OF ORE RESERVES

WHITE MESA MINING DISTRICT

Indicated Ore

	Reasonably assured	In probable extensions	Totals
Grading 1 to 4% (in scattered small bodies).	80,000	180,000	260,000 tons
Grading 0.3 to 1% Cu (in a few large and many small bodies).	535,000	1,465,000	2,000,000 tons
	615,000	1,645,000	2,260,000 tons

Inferred Ore

	In concealed orebodies	
In area west of Eastern Star fault	7,250,000	
In area east of Eastern Star fault	6,750,000	
	14,000,000	14,000,000 tons

TOTAL INDICATED AND INFERRED RESERVES..... 16,260,000 tons

Variations in grade are further illustrated in the following table of typical average assays from various parts of the district:

Description	Samples	oz. Au.	oz. Ag.	% Cu	Remarks
Little Dick claim					
In and along walls of open cut	16	.001	.32	1.23	
40' NE and NW of N. end open cut	2	.001	.18	1.15	25 channel samples
South central part of claim	3		.15	.70	1.12% Cu
West central part of claim	1		.14	.59	
NW corner of claim	3		.20	1.05	
Grand Pacific claim					
West central part of claim	6		.23	1.02	12 channel samples
Central part	3		.18	.82	.82% Cu
South central part	3		.21	.44	
California claim					18 channel samples
Central part of claim	8		.14	.98	.82%
West part	10		.13	.69	
Nannie E claim					
North end	6		.18	.54	
Copper World claim					16 samples-channel
North part open cut	10	.001	.44	.69	.71% Cu
South part	6	.001	.26	.74	
Ida M. Smith claim					
NW corner claim	4	.001	.22	.55	
SE corner	1	.001	.14	1.57	
NE corner	1	.001	.16	1.02	
Eli claim,					
North central part of claim	4	.001	.32	.80	
Gopher claim					
SW Central part of claim	1	.001	.20	1.35	

The area west of the Eastern Star fault contains most of the larger ore bodies and is believed to offer the best chances for mining development. Most of the large, low-grade copper deposits occur in this part of the district where they lie north of the Ida M. Smyth fault. The Little Dick-Grand Pacific, California, and Copper World bodies together account for 323,000 tons of measurable or indicated and 1,130,000 T of inferred low grade ore in the estimates given. The Copper Hill area on the Lardun lease affords some promise as does the Dutchman Claim. It is considered possible that about 10% of the uplands in this part of the district are mineralized to an average depth of 50 feet giving 7,250,000 tons of implied ore which probably cannot be found economically.

Numerous small pods of high-grade ore occur in the eastern part of the district. There are a few large bodies, however. Approximately 1% of the uplands east of the Eastern Star fault are believed to be mineralized through an observed interval of 150 feet. The resultant 6,750,000 tons of implied ore will be costly to find and probably cannot be recovered economically.

Outlook

Possibilities for large copper-mining operations in the White Mesa Mining District are not high in the immediate future. The summation of reserves indicates a large probable and possible tonnage of ore which, at first glance, might be considered attractive to mining companies. The grade, however, is low and will average less than one percent copper. There is little to suggest that numerous large deposits of this low-grade material will be found and abundant reason to believe that most of the bodies will contain not more than a few thousands of tons. Deposits such as the Little Dick, Copper World, and California are clearly in the minority.

Exploration for reserves in the area will be costly because of the large areas which must be drilled on close centers in order to block out known ore

bodies or to find inferred ones. Open-pit mining operations will require the removal of large tonnages of barren or very low-grade sandstone in order to search out and recover ore pods which may characterize the supposed large tabular deposits. Furthermore such operations can not long be restricted to a narrowly circumscribed portion of the district. Costs of constructing roads, trucking ore to mills, and moving mining machinery from one location to another will therefore be considerable.

The White Mesa Mining District is 112 miles from the rail head at Flagstaff, Arizona, and approximately 175 miles from the nearest smelter at Clarkdale, Arizona. Beneficiation will be necessary to obtain, in significant tonnages, a product which can be profitably shipped. The White Mesa ore will leach well but the present water supply of the district is inadequate for such an operation, and conditions are unfavorable for any large increase by additional drilling. Although it would be physically possible to obtain surface water from Colorado River at Lee's Ferry or from Navajo Creek, about twenty miles north or northeast of the district and at far lower elevation, costs of installing and maintaining a pumping system would probably be prohibitive.

A dry milling process which is reported to yield a 20 percent concentrate with a rather high efficiency has been developed by the Mardun Company. As the process is still in the experimental stages, however, there are no data on costs and recovery in large milling operations. It is possible that this process may offer a solution to concentrating problems in the district.

It is suggested that any large-scale attempt to develop the copper reserves in the district be prefaced by a careful analysis of mining and concentrating costs based on the mining of many scattered small bodies which will average not

higher and probably less than one percent copper. Efforts to block out ore should be initiated only in the event that such an economic survey points to the possibility of development based on minimum rather than maximum tonnage expectations.

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MINERAL RESOURCES

GEOLOGY - EVALUATION - USES

NAVAJO - HOPI INDIAN RESERVATIONS
ARIZONA - UTAH

Volume I

George A. Kiersch
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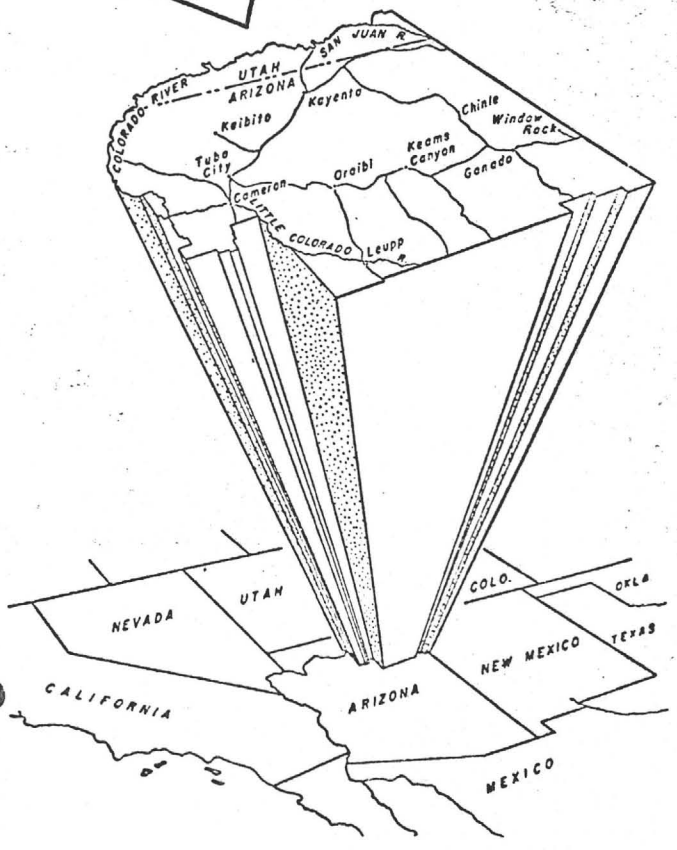
METALLIFEROUS MINERALS AND MINERAL FUELS



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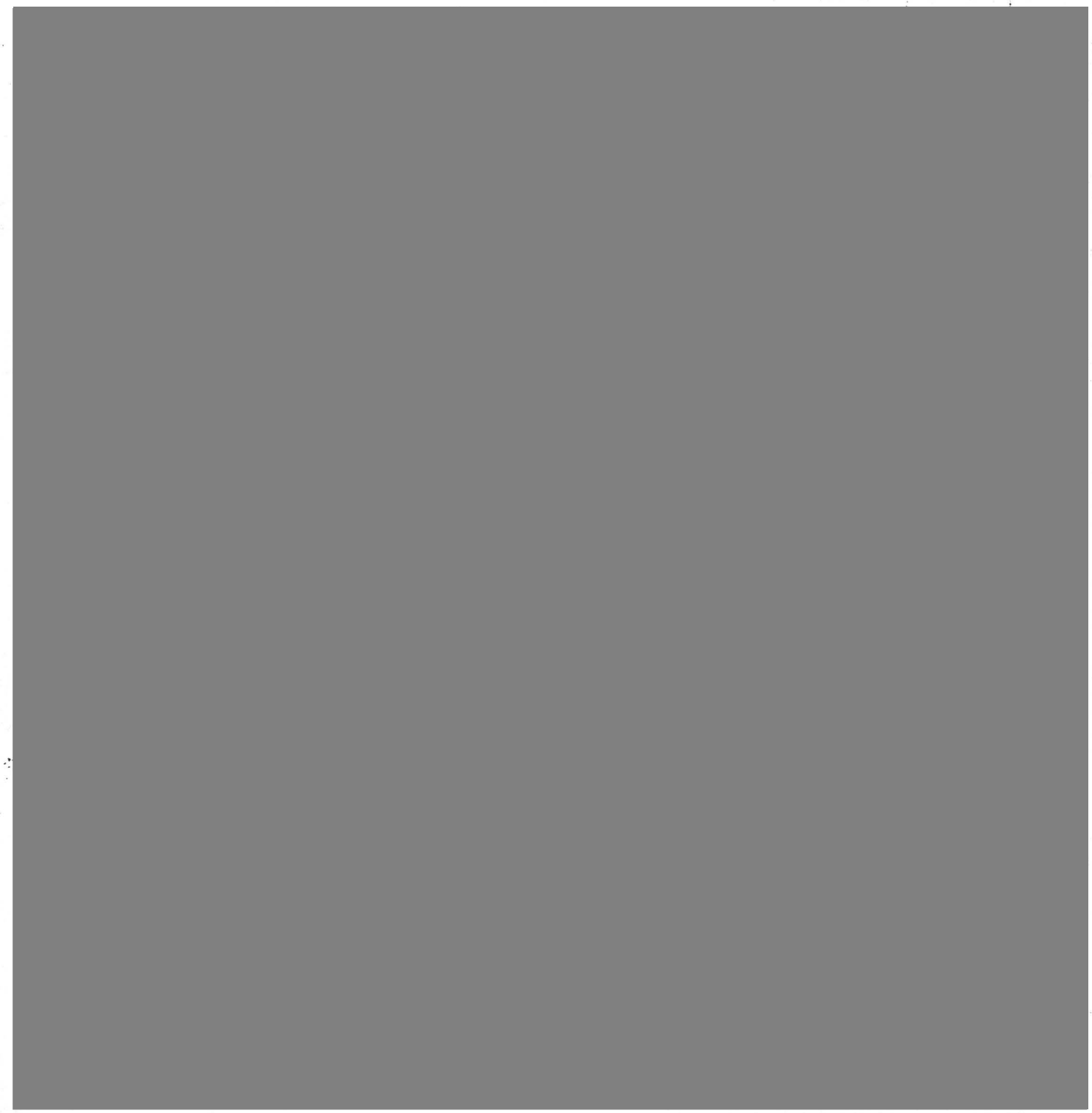
Copper

By E. B. Mayo



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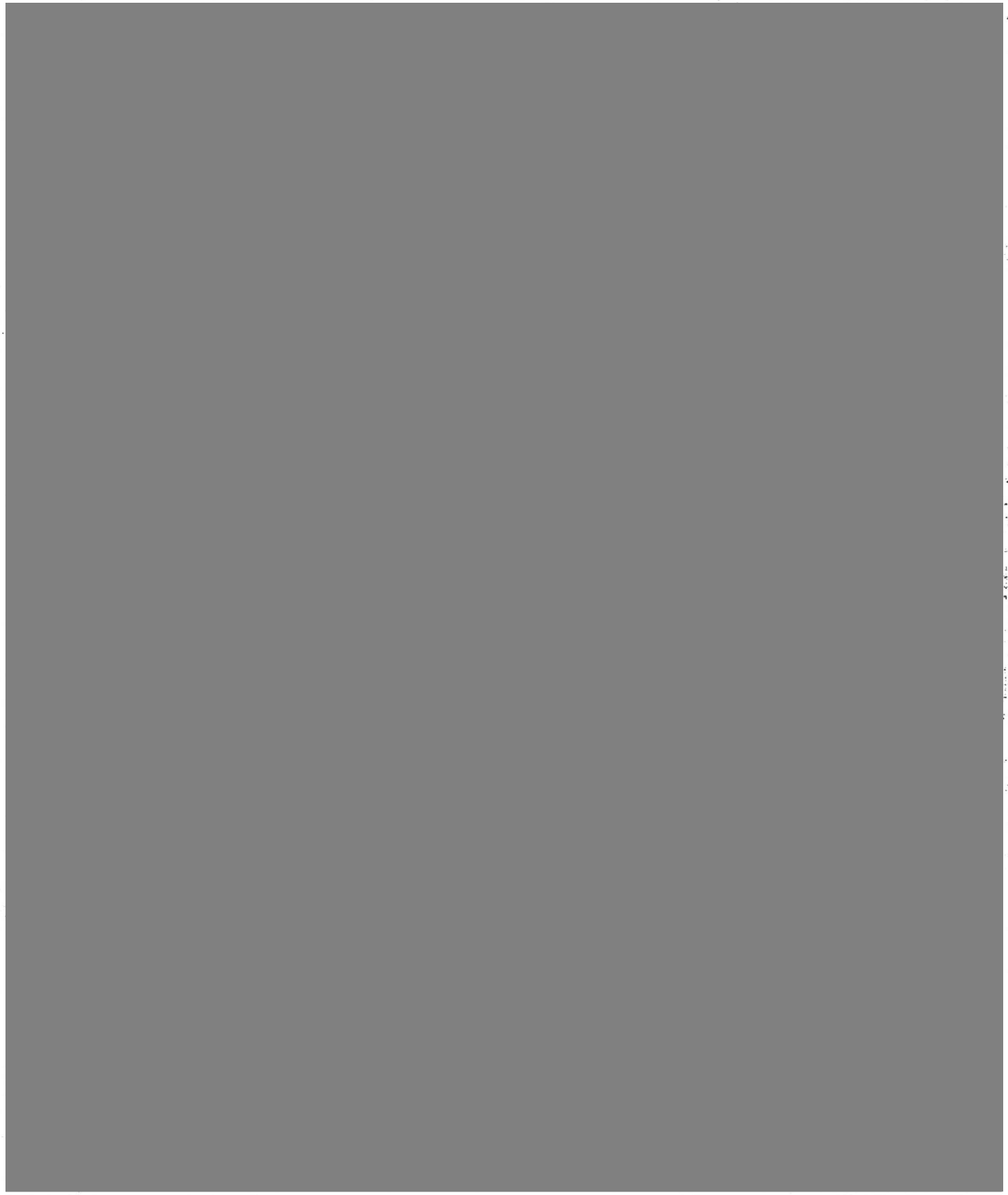

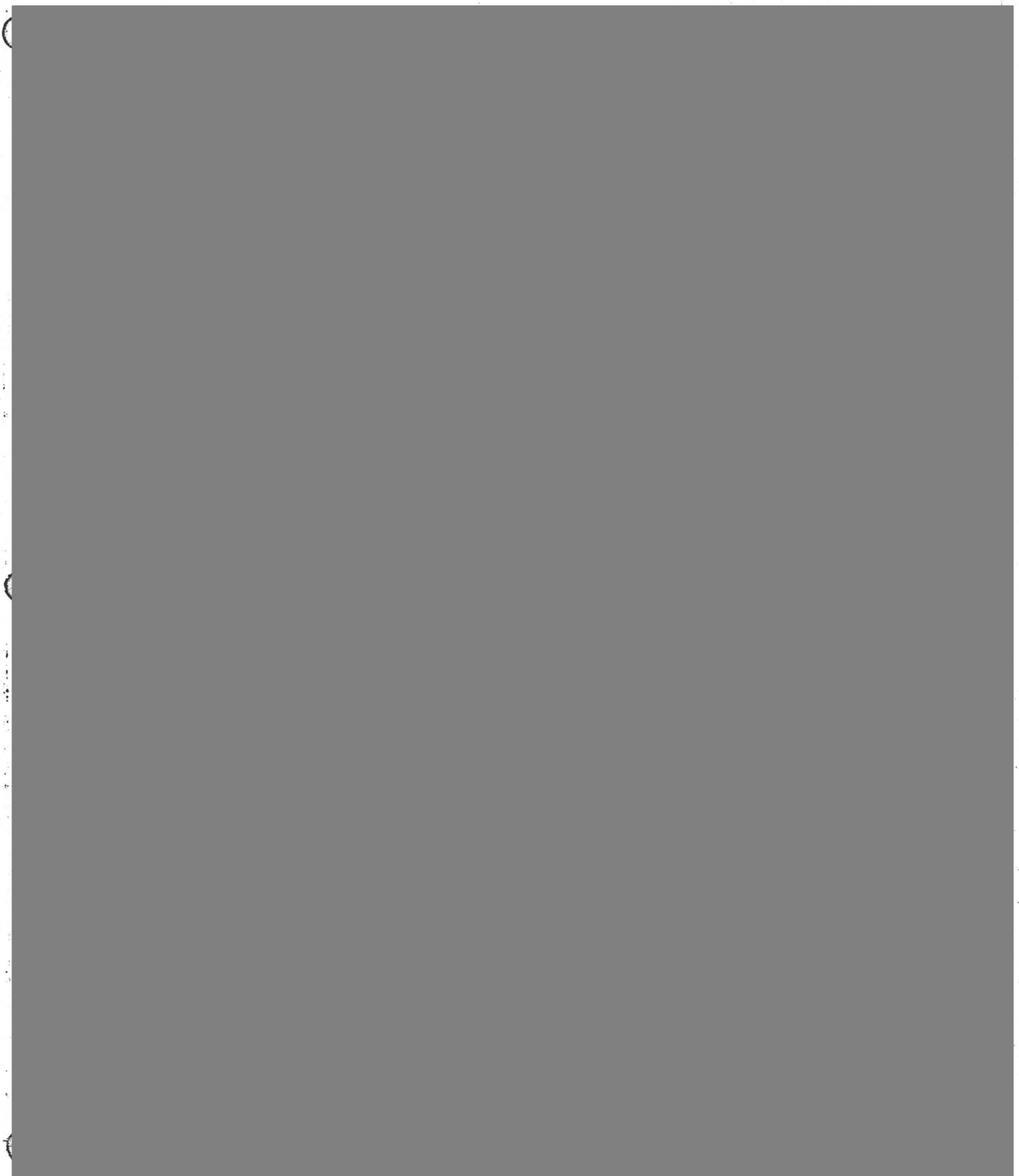

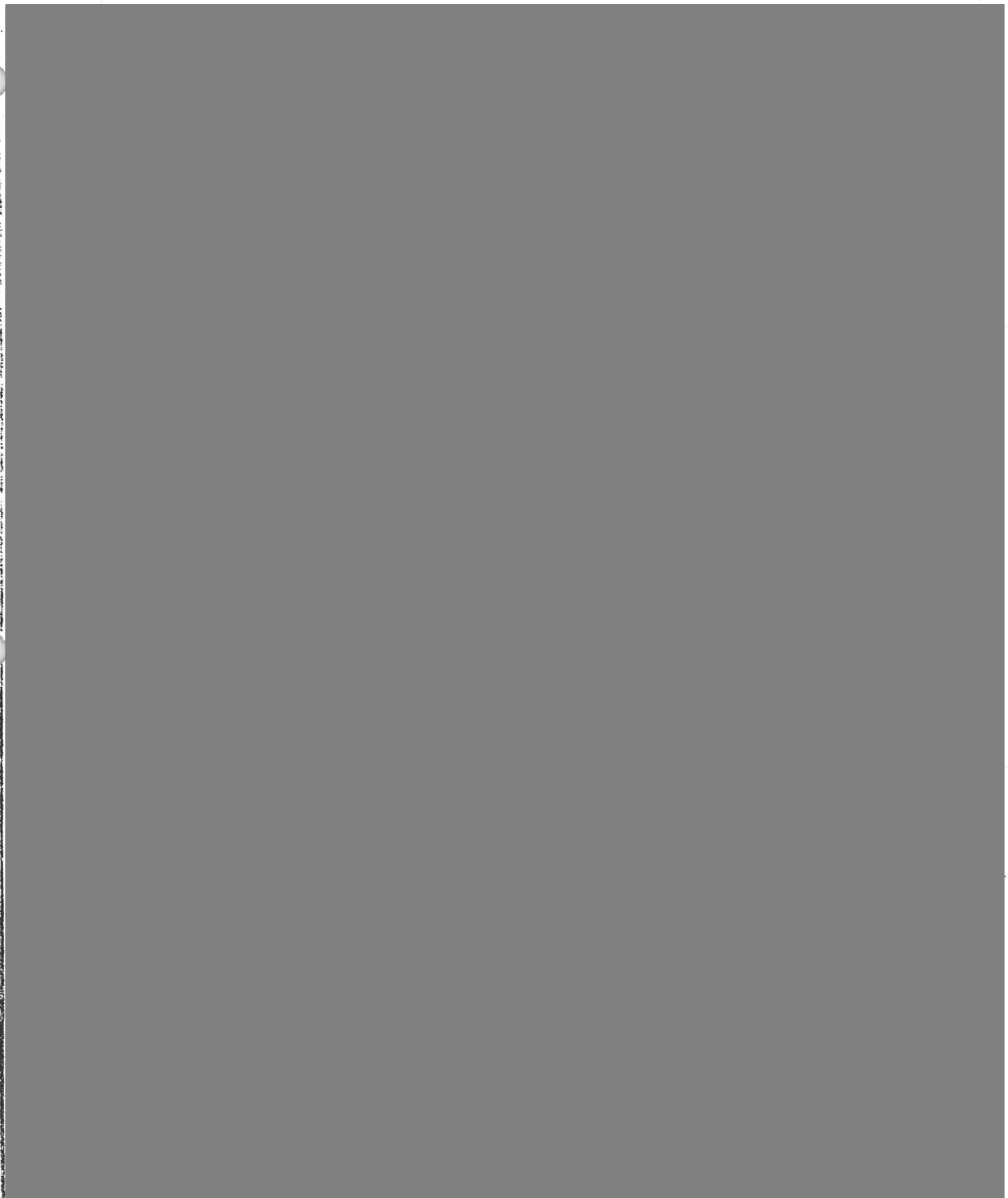

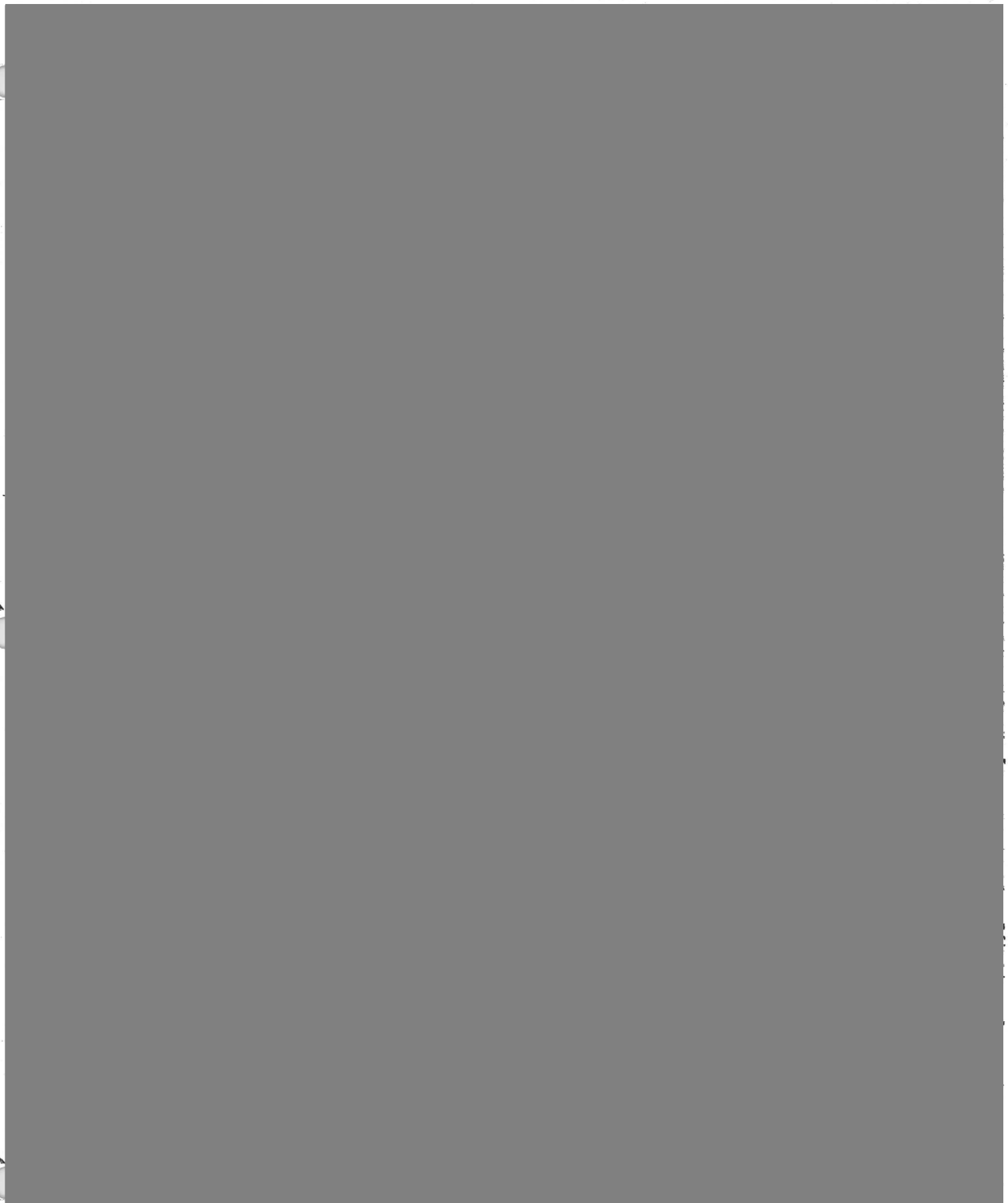

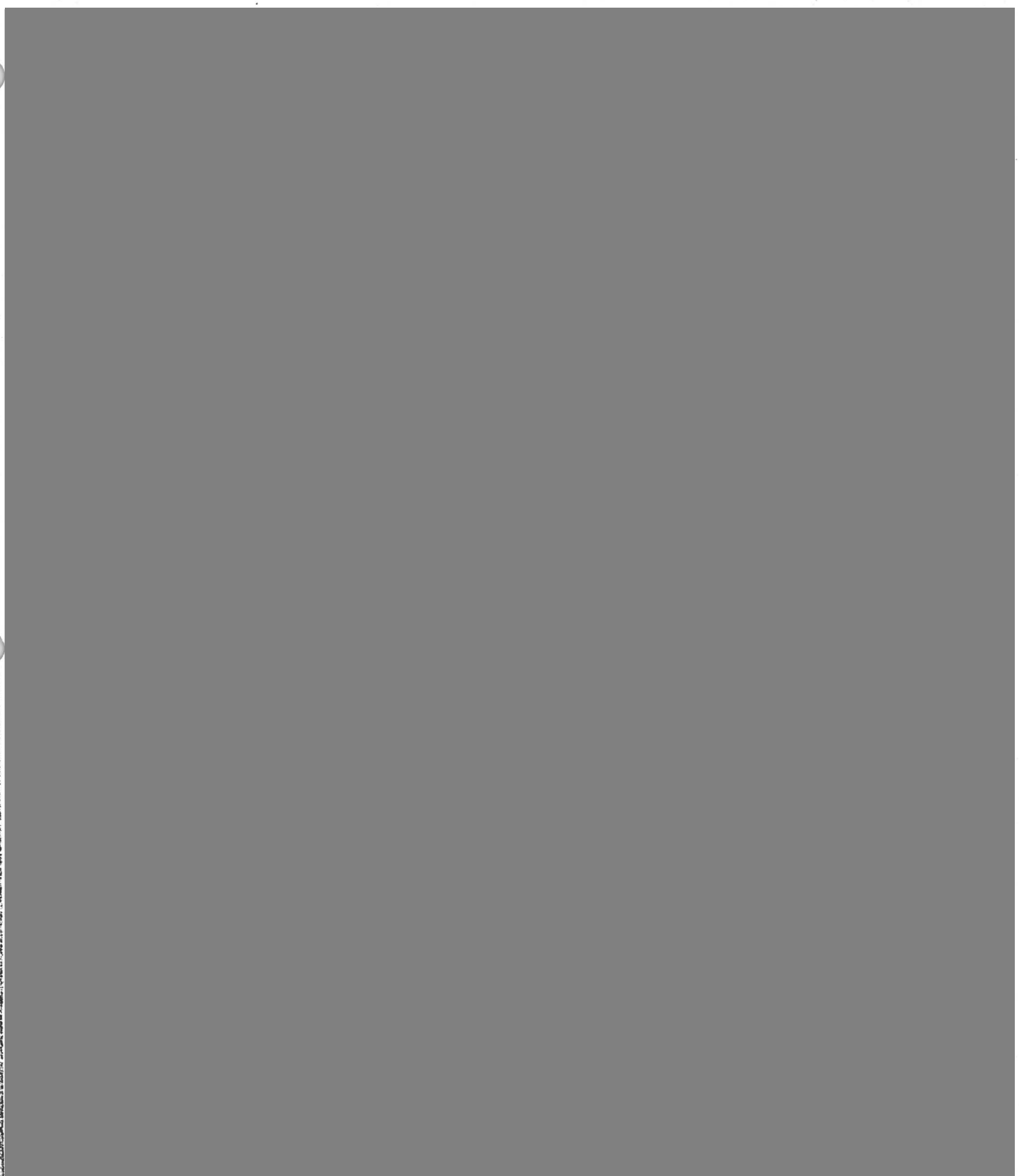

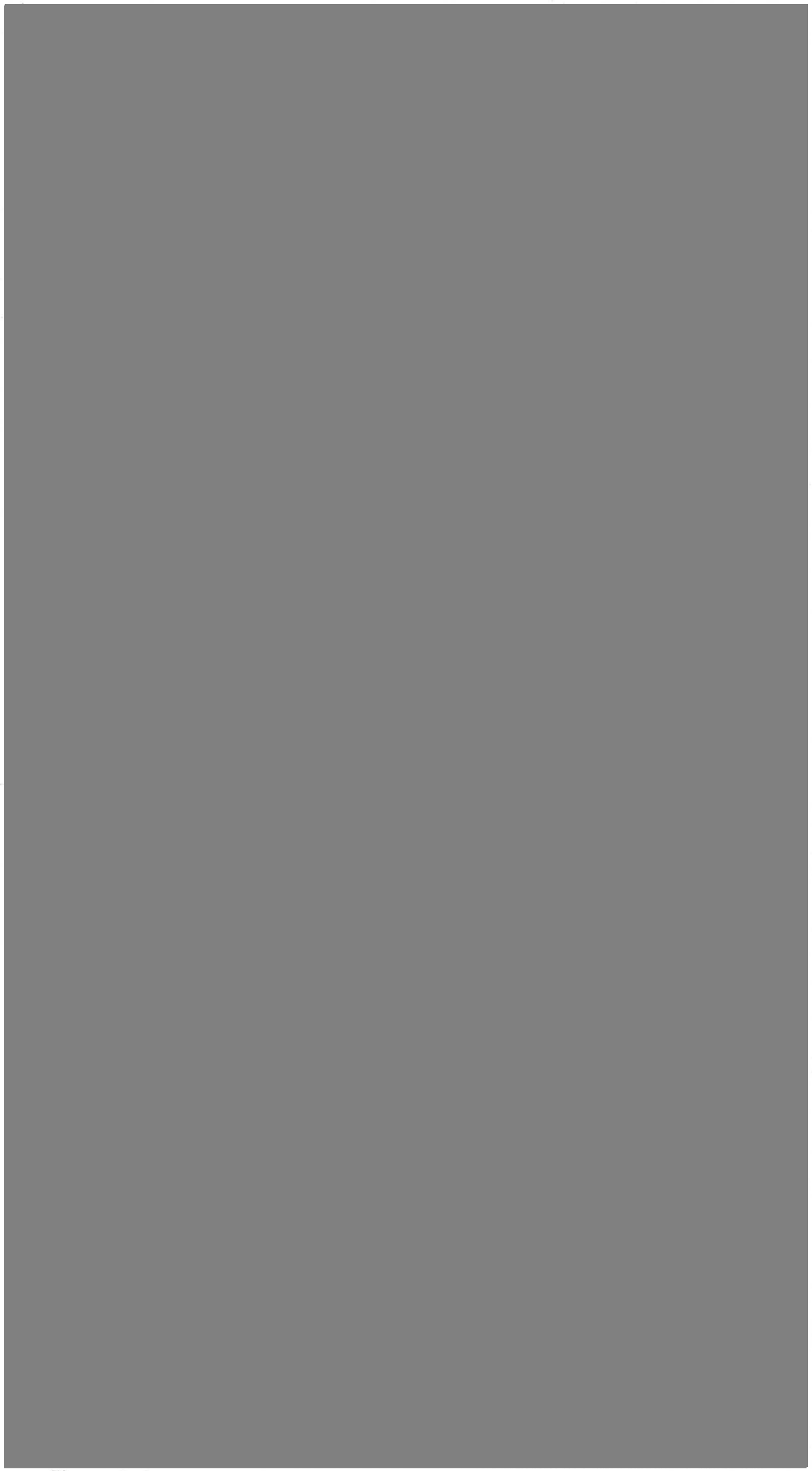

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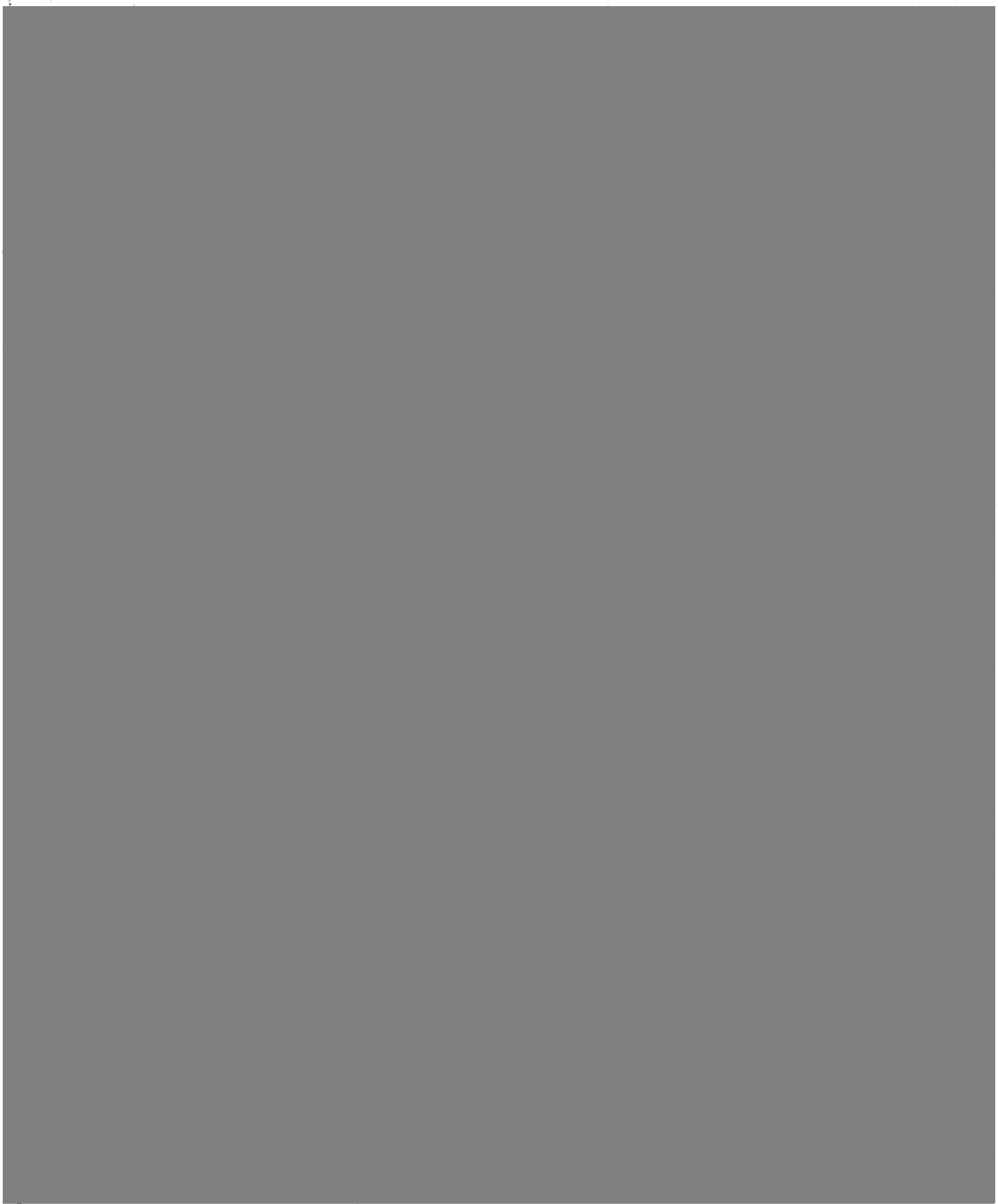

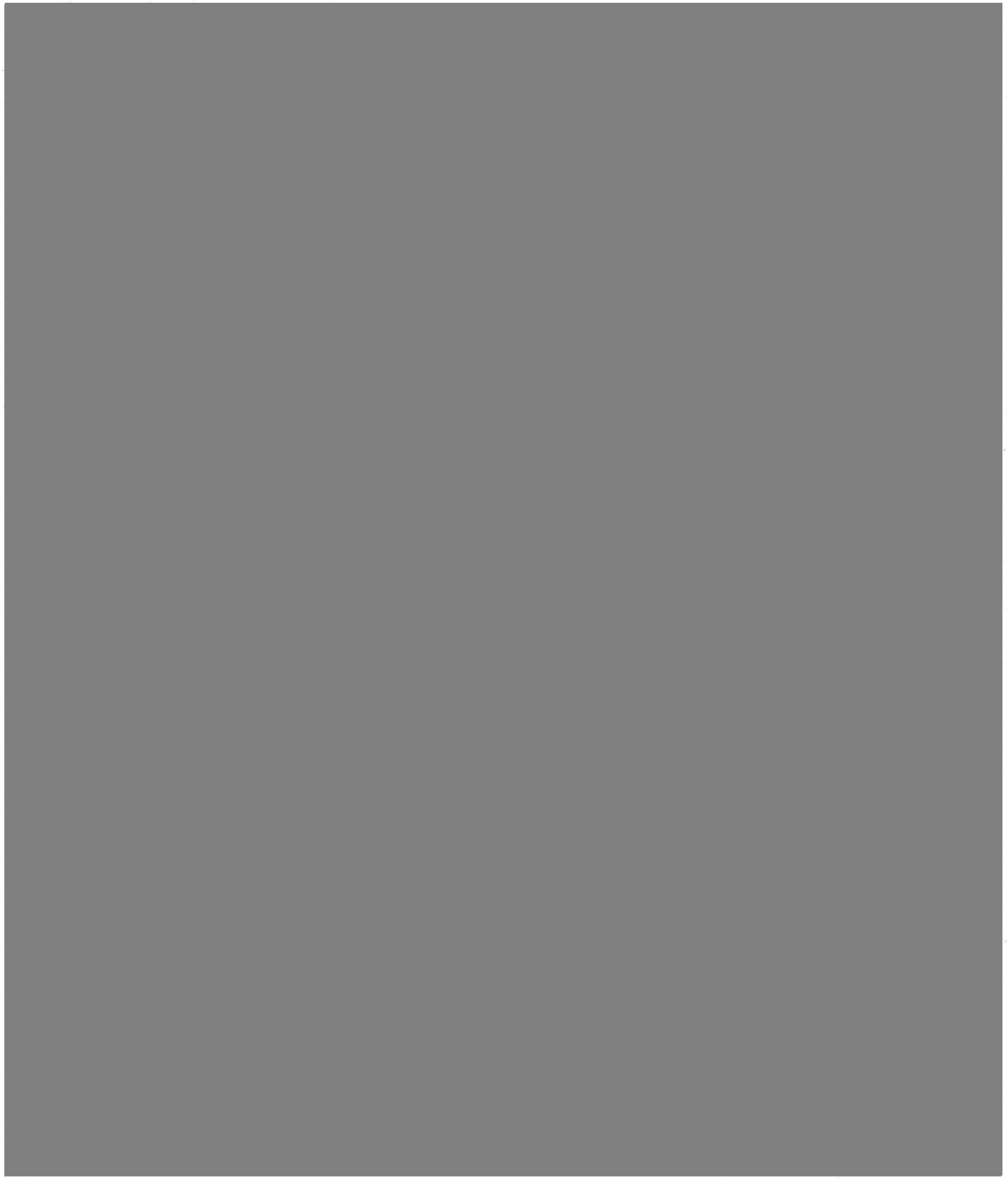

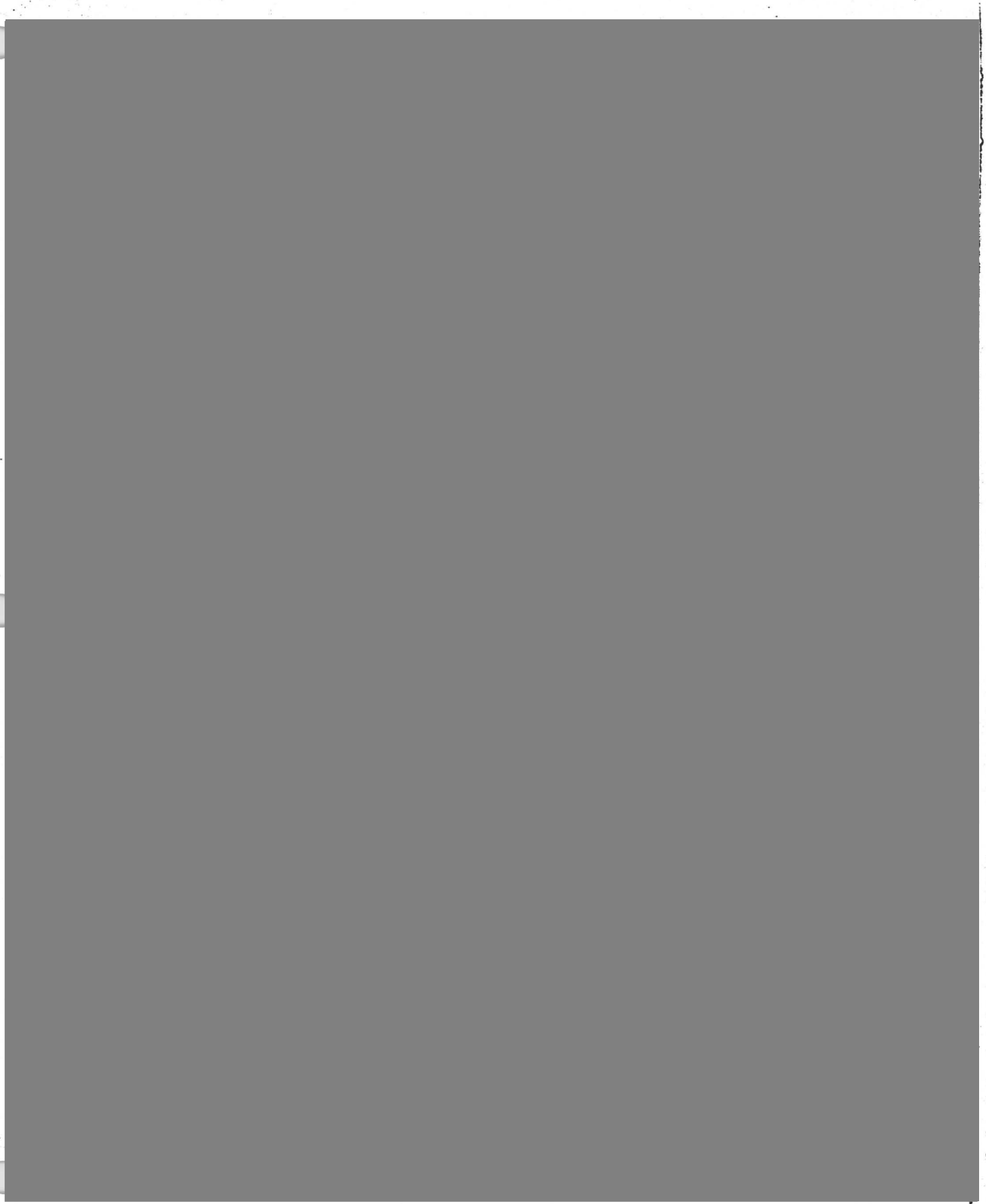

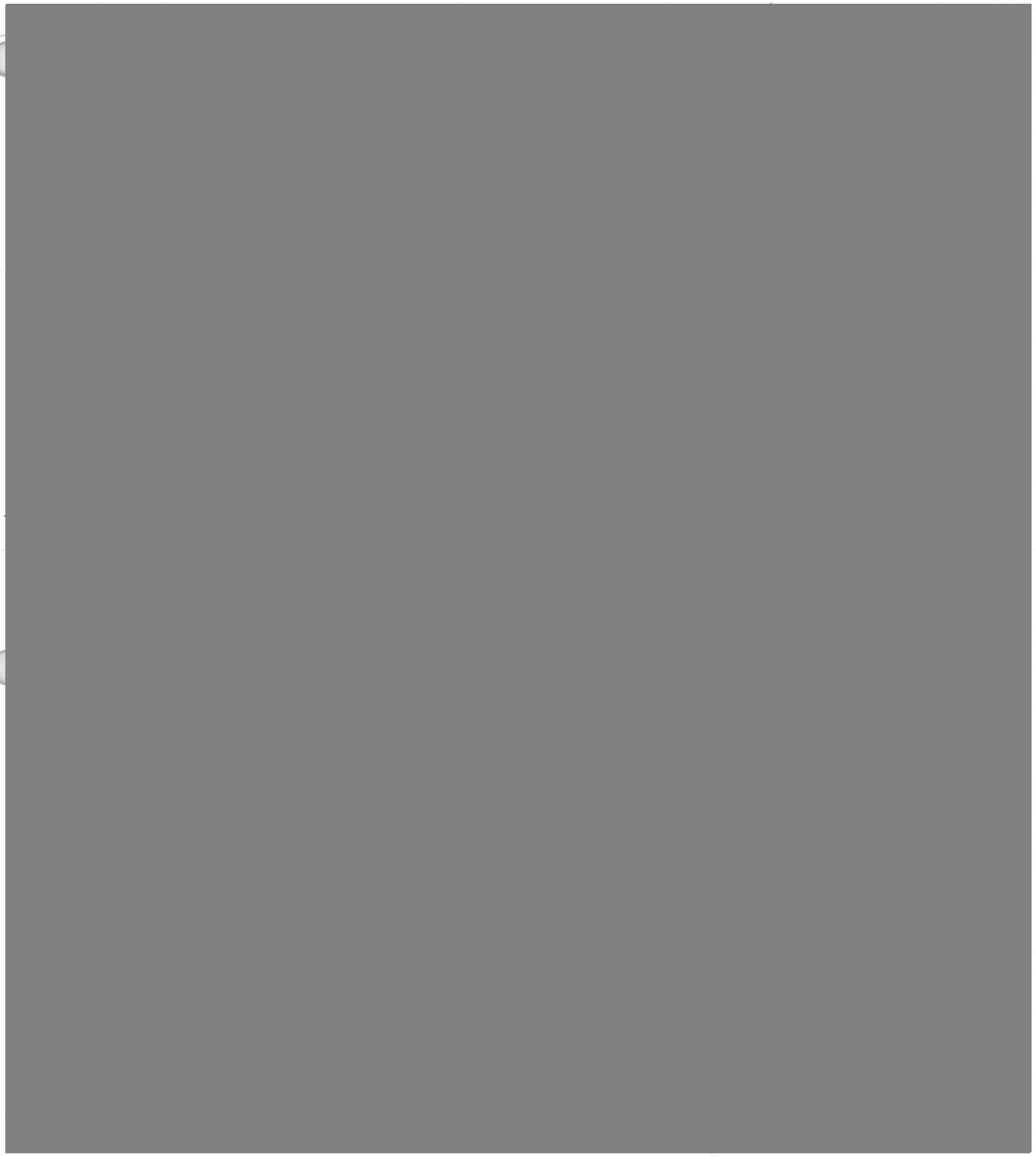

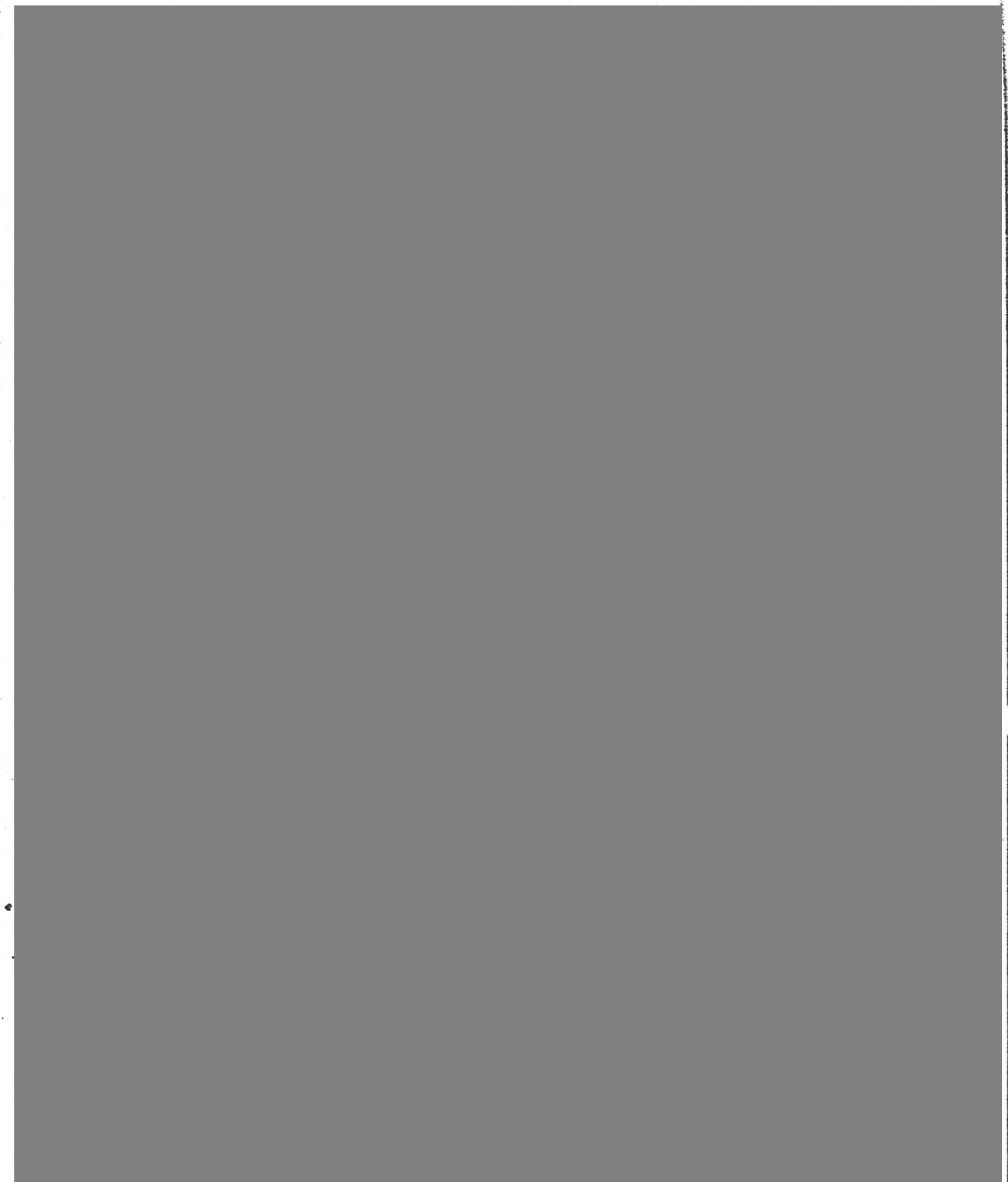

Figure 4.