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FLOTATION OF THE OXIDIZED ORES OF ZINC

BY

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A

THESIS

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Approved by A. Legsdin

Associate Professor of Mineral Dressing

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CONTENTS

ILLUSTRATIONS

TABLES

INTRODUCTION

There is no satisfactory method of concentrating the finely disseminated oxide ores of zinc. Gravity methods of concentrating such ores may be used for coarsely crystalline materials in which the zinc material is free at approximately 10- to 35-mesh or coarser. In addition, gravity methods of concentration do not give a satisfactory separation on those ores in which the difference between specific gravity of the desired mineral and the gangue mineral is small. As a result there is need for a method of beneficiating various deposits of oxidized zinc ores.

The two commercially important oxidized zinc minerals under consideration are smithsonite, the zinc carbonate and hemimorphite, frequently referred to as calamine, the silicate of zinc. Deposits of the oxide minerals are numerous but unless the ore is selectively mined or amenable to concentration by hand picking or gravity methods, it has not been possible to produce concentrate of a satisfactory grade and recovery.

These combined factors led to the selection of this subject as a research problem.

The object of the present investigation has been to investigate various reagents and conditions in an attempt to produce, by flotation, concentrates of satisfactory grade and recovery from some oxidized zinc ores of Missouri. Since the selling price of zinc silicates and zinc carbonate concentrates is based on a zinc content of 40 percent the goal of this investigation was to produce a concentrate of at least 40 percent zinc at a maximum recovery.

SMITHSONITE

Smithsonite is the carbonate of Zinc ($ZnCO_3$), a secondary mineral formed from the oxidation of the sulphide mineral sphalerite (ZnS). It is often referred to as "dry bone" by miners, which is the porous variety and the ore most commonly found. The hardness of smithsonite on the Mohs scale is 5.5 and its specific gravity ranges from 4.30 to 4.45.(1) Smithsonite crystallizes in the rhombohedral system, however, the crystals are rarely well formed. It is found deposited in veins as well as in beds, especially in company with galena and sphalerite, with copper and iron ores, calcium and magnesium carbonates and frequently with manganese carbonate. Smithsonite usually occurs in calcareous rocks and is commonly associated with hemimorphite and limonite.

The oxidized zinc ore usually forms in openings vacated by the sulphide upon oxidation, or else in the unoccupied spaces in the adjacent cavities and cracks. The pure smithsonite contains 52.1 percent zinc.

HEMIMORPHITE

Hemimorphite is the silicate of zinc (H_2ZnSiO_5), often referred to as calamine. The crystals are usually thin tabular or pyramidal. It has a prismatic cleavage, the fracture is uneven to conchoidal, a hardness of 4.5 to 5 on the Mohs scale and a specific gravity of 3.4 to 3.5.(2) It fuses easily and gelatinizes readily with acids. Hemimorphite is of secondary origin formed by the action of silica-bearing waters upon other zinc minerals. The pure hemimorphite contains 54.2 percent zinc.

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(1) Ford, W. E. Dana's Textbook of Mineralogy. Wiley, N. Y. 1932, pp. 520-521.

(2) Ford, W. E., Op. Cit. pp. 632-633.

The zinc silicate is usually found in veins or beds in stratified calcareous rock accompanying sulfides of zinc, iron or lead and associated with smithsonite, sphalerite, galena, cerussite and anglesite, hydrozincite, zincite and willemite may also be present.

DEPOSITS AND PRODUCTION OF OXIDIZED ZINC ORES

Missouri

Table I gives the annual production and value of zinc carbonate and zinc silicate concentrates produced from 1915 to 1943 inclusive. From 1933 to 1940 the output of zinc carbonate concentrates was very small. From 1940 to 1943 the production of zinc carbonate concentrates increased. Table II gives the value per ton and the average zinc content of zinc carbonate and zinc silicate concentrates produced in southwestern Missouri from the years 1915 to 1943 inclusive. The figures given for the years 1940 to 1943 inclusive are values for zinc carbonate and silicate concentrates produced from crude ore only.

Table I. Annual Production and Value of Zinc Carbonate and Zinc Silicate in Southwestern Missouri from 1915 to 1943 inclusive(3)

Year	Quantity (short tons)	Value	Year	Quantity (short tons)	Value
1915	24,351	$ 1,203,998	1930	1,696	$ 40,698
1916	25,864	1,203,998	1931	377	4,760
1917	30,693	1,247,830	1932	404	4,248
1918	17,581	567,291	1933	1,325	19,887
1919	11,510	314,277	1934	1,200	17,437
1920	9,433	336,093	1935	1,400	20,561
1921	60	643	1936	621	10,762
1922	3,008	63,917	1937	1,690	43,411
1923	3,774	100,272	1938	1,022	17,931
1924	1,453	35,294	1939	949	16,757
1925	2,269	69,874	1940	807	10,965
1926	3,669	115,982	1941	1,277	14,355
1927	1,357	35,632	1942	1,510	23,940
1928	987	20,693	1943	1,037	51,261
1929	1,352	28,710			

Table II. Tenor of Zinc Silicates and Zinc Carbonates Produced in Southwestern Missouri(4)

Year	Value (per ton)	Zinc Content Percent	Year	Value (per ton)	Zinc Content Percent
1915	$ 45.00	39.3	1930	$ 24.00	40.1
1916	50.21	39.4	1931	12.63	39.0
1917	40.50	39.7	1932	10.51	39.8
1918	32.27	37.1	1933	15.01	39.4
1919	27.33	40.3	1934	14.53	39.3
1920	35.50	39.8	1935	14.62	38.0
1921	10.57	38.3	1936	17.33	40.1
1922	21.25	39.2	1937	25.69	40.5
1923	26.57	36.6	1938	17.54	44.4
1924	24.29	39.3	1939	17.66	45.0
1925	30.80	38.2	1940	12.13	25.7
1926	31.61	39.3	1941	11.24	22.5
1927	26.26	38.2	1942	15.85	23.2
1928	20.97	39.5	1943	49.43	35.3
1929	21.24	40.2			

(3) Mineral Resources of the United States, 1915 to 1931, inclusive, and Minerals Yearbooks, 1932 to 1943, inclusive.United States Bureau of Mines.

(4) Mineral Resources of the United States, 1915 to 1931, inclusive, and Minerals Yearbooks, 1932 to 1943, inclusive, United States Bureau of Mines.

In Figure 1 the zinc carbonate and zinc silicate concentrate production for southwest Missouri has been plotted. The average value of the concentrate produced for each year has also been plotted to illustrate the effect that market prices has had upon the production of zinc carbonate and silicate concentrates.

Mines which have produced zinc carbonate or zinc silicate concentrates within the past several years and producing at present are as follows:

Name of Mine	Location
Valle	Jefferson County, Valle Mines, Missouri
Alice	18 miles west of West Plains, Missouri
Wallace	Aurora, Missouri
Quick Bury	Grandby, Missouri
K.D.F.	Stark City, Missouri
Rex	West Plains, Missouri
G and G	West Plains, Missouri
Sharp	West Plains, Missouri

Alice Mine

History The Alice Mine is the largest open pit zinc carbonate mine in Ozark and Howell County, Missouri. Size of the mine is roughly 300 feet long by 250 feet wide with an average depth of 60 feet. The mine was opened up about 1890. Production reports are scarce, but an estimated 85,000 tons of sorted and washed ore, with a grade from 17 to 36 percent zinc, have been produced from the Alice Mine, Rex Mine, G and G Mine and the Sharp Mine.

From 1940 to 1942, 900 tons of ore were shipped from the Alice Mine. The average grade of these shipments was 17.30 percent zinc. Because of the difficulties of beneficiating this ore to an acceptable smelter grade by gravity concentration, the operation has been small and intermittent.

Geology The predominating country rock is a fine-grained light-colored magnesian limestone of the lower Jefferson City formation. The beds of this formation are essentially horizontal.

The surface overburden is of a dark red clay and gravel; below this is a thin bed of chert which the miners consider as the beginning of the ore.

Ore Reserves The estimated zinc carbonate reserves of the Alice Mine is 29,256 tons of ore containing 8.81 percent of zinc.(5) These estimates are based on sampling done by the United States Bureau of Mines. The estimated zinc carbonate ore in the four mines, Alice, Rex, G and G, and Sharp, is 49,500 tons containing an average zinc content of 8.51 percent.

Arkansas

Northern Arkansas has been of little importance in the United States, as a producer of sulphide zinc ores, but it assumed a very high rank, especially in 1916 and 1917 as a producer of oxidized zinc ores. The production of northern Arkansas from 1907 to 1930 has been compiled by the United States Geological Survey and has been, in round figures, 51,315 short tons of zinc carbonate and zinc silicate concentrates valued at $2,254,744.(6)

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(5) McMillan, W. D., and Swanson, Arthur. Zinc Carbonate Deposits. United States Bureau of Mines, Preliminary War Minerals Report, 1943, Unpublished.

(6) McKnight, Edwin T., Zinc and Lead Deposits of Northern Arkansas. United States Geological Survey. Bulletin 853. p. 6. 1935.

Incomplete oxidation resulting in mixtures of zinc sulfides and carbonate or silicate is common of the ore found in Arkansas.

The production of oxidized zinc concentrates has been small in recent years; during 1943 the Minerals Yearbook states that zinc mining in Arkansas was confined to intermittent small scale operations, 110 tons of carbonate and silicate zinc ores containing 34.55 percent zinc was shipped to the Fort Smith, Arkansas smelter.(7)

California

Zinc production in California which had been negligible in recent years, expanded in 1941. Most of the output was carbonate ore, much of which was shipped to the Pacific Oxide Company for the manufacture of zinc oxide. The production of Inyo County, California for the year 1941 is reported as 416 tons of zinc carbonate ore which contained 327,058 pounds of zinc.(8)

Colorado

The following figures show the quantities of oxidized zinc ore produced in the Leadville District of Colorado from the time of the first shipments in 1910 to the end of 1916.

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(7) Martin, A. J. Gold, Silver, Copper, Lead, and Zinc in the Central States. Minerals Yearbook, 1943. United States Bureau of Mines. p. 296.

(8) Gaylord, H. M. and Merrill, Charles White. Gold, Silver, Copper, Lead and Zinc in California. Minerals Yearbook, 1941. United States Bureau of Mines. p. 248.

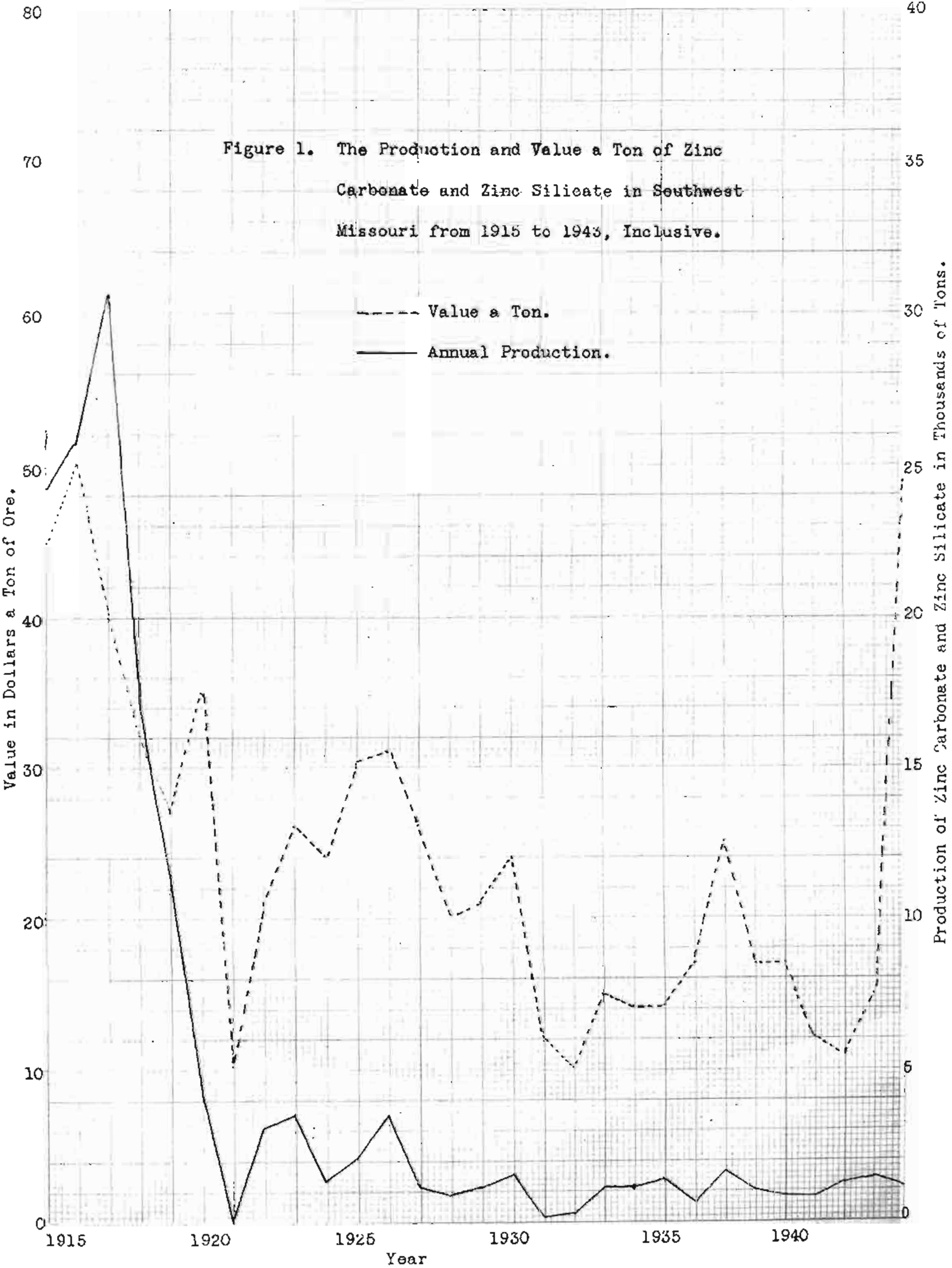

Figure 1. The Production and Value a Ton of Zinc Carbonate and Zinc Silicate in Southwest Missouri from 1915 to 1943, Inclusive.

Year	Oxidized Ores Quantity (short tons)	Percent of Zinc
1910	8,059	30.1
1911	83,905	31.1
1912	142,782	29.2
1913	135,760	27.45
1914	113,881	24.3
1915	82,592	22.48
1916	85,513	21.52

Most of the ore thus far mined has come from the immense body in Carbonate Hill, which extends through the claims controlled by the Western Mining Company and a few adjoining claims. Smaller amounts have come from Fryer Breece, Iron, Printer Boy and Rock Hills, showing that the oxidized zinc ores like the oxidized lead ores are distributed throughout the district.(9)

New Jersey

Franklin mill yields annually about 773,000 short tons of ore containing about 98,000 tons of zinc. The ore is a coarse aggregate of franklinite 50 percent, willemite 20 to 30 percent, zincite 2 to 6 percent and calcite 3 to 11 percent.(10)

Nevada

In southwestern Clark County in southwestern Nevada weathering and alteration of the zinc sulfide have proceeded to so great a degree that sphalerite is rarely found. The chief mineral is earthy hydrozincite, the hydrated carbonate. Smithsonite and hemimorphite are less important but are widespread. An important feature of the zinc-bearing deposits

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(9) Loughlin, G. F. The Oxidized Zinc Ores of Leadville, Colorado. United States Geological Survey. Bulletin 681, p. 14. 1918.

(10) Lindgren, Waldemar, Mineral Deposits, N. Y. McGraw-Hill, 1943, p. 737.

is the presence of large concentrations of zinc carbonate and silicate ore below or in the lower area of primary mineralization. (11)

Tennessee and Virginia

In Virginia and Tennessee primary zinc sulfide deposits in the shaley dolomite have been oxidized to hemimorphite and smithsonite, which occur in nodules and mineable masses in residual clay overlying the dolomite.

The Universal Exploration Company at Jefferson City, Tennessee has a small gravity concentrating mill which it uses intermittently to concentrate zinc carbonate ores. (12)

Utah

Large bodies of clean zinc carbonate that have been formed remote from the sulfide ore are found at Tintic, Utah. (13)

Wisconsin

Several cars of zinc carbonate ore were shipped from the Clark No. 2 mine in the Highland District in 1941. (14)

Foreign

Silesia in Poland remains one of the world's important zinc producing regions. The replacement ore occurs along two horizons. The lower about 400 feet deep carrying sulfide of zinc and the upper is a

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(11) Jackson, Chas. F., Kniebel, John B., and Wright, C. A. Lead and Zinc Mining and Milling in the United States Current Practices and Costs. United States Bureau of Mines. Bulletin 381, p. 41, 1935.

(12) Rouch, G. A. The Mineral Industry During 1941. pp. 585-586. McGraw-Hill, N. Y. 1942.

(13) Bateman, Alan M. Economic Mineral Deposits. pp. 241-271. Wiley, N. Y. 1942.

(14) Lindgren, Op. Cit. p. 427.

bed of smithsonite of considerable thickness. The ore contains about 17 percent zinc. In 1930 Polish reduction works produced 174,000 metric tons of zinc.

In the Moresnet District in Belgium, Luxembourg and Rhinish, Prussia are found masses of calamine which appear near the surface and extend to depths of 160 feet. In some cases, notably at Vieille Montagne, the calamine deposits were of enormous size and reached a depth of 330 feet, sulfides appearing below these depths. The quantity of ore is said to diminish in depth. A considerable part of the world's production of zinc has been obtained from these deposits.(15)

USES OF OXIDIZED ORES OF ZINC

Smithsonite and hemimorphite concentrates are used primarily in the manufacture of zinc oxide. Of the methods used for manufacturing zinc oxide the American method is used predominately in this country.(16)

Any ore of zinc can be used as a raw material in the manufacture of zinc oxide. In decreasing order of their economic importance they are: sphalerite, smithsonite, hemimorphite, willemite, and zincite.

When carbonate ores (smithsonite) are utilized, carbon dioxide is driven off and goes forward with the furnace gases leaving ZnO as a residue, according to the simple equation $ZnCO_3 \rightarrow ZnO + CO_2$. Thus we have zinc oxide as the real raw material in the oxide furnace.

In the case of silicates the silica takes no part in the reactions and remains behind as a furnace residue.

The crude zinc oxide usually contains from 20 to 90 percent zinc oxide. The zinc oxide is then reduced to metal at a temperature

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(15) Lindgren, Op. Cit. p. 426.

(16) Furnas, C. C. Rogers Industrial Chemistry, p. 973. Van Nostrand, N. Y. 1942.

considerably above the boiling point of the metal. From this stage the metallic vapors are converted to zinc oxide by admitting air which burns the Zn to ZnO. Low-grade zinc ores (sulphide or oxide) are now being handled metallurgically in the "Waelz Process."(17) The ore is mixed with a required quantity of coke to reduce the zinc and is heated in a long rotating cylindrical kiln. The zinc is driven off due to volatilization in contact with the carbon of the coke and is then oxidized in the kiln gases. The "zinc fume" is collected and sintered to recover the metal or without sintering, is sold directly to paint manufacturers.

The reduction, volatilization and reoxidation of the zinc proceeds as follows:

$$ZnO + C = CO + Zn \text{ (vapor)}$$
$$Zn \text{ (vapor)} + CO + O_2 = ZnO + CO_2$$

The presence of lime in the kiln feed is required when zinc sulphide ores are treated by this process to "fix" the sulphur.

$$ZnS + CaO + C = Zn \text{ (vapor)} + CaS + CO$$
$$Zn \text{ (vapor)} + CO + O_2 = ZnO + CO_2$$

Zinc oxide possesses properties that make it valuable in paint, enamels, rubber, paper, ceramics, floor coverings and textiles.

In the manufacture of rubber zinc oxide is an important reinforcing filler. The reinforcing fillers are very finely divided, usually through 300-mesh. Since compounds of copper and manganese are very deleterious to rubber, zinc oxide used as a rubber filler must not contain more than 0.001 percent of these elements. The zinc oxide increases resistance to abrasion, toughness, resistance to swelling,

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(17) Harris, William E., "Waelz Process" A.I.M.E. Transactions, vol. 121, p. 702. 1936.

imparting increased tensile strength, hardness, compressive strength and resistance to steam.(18) Zinc oxide is often utilized extensively as a pigment to give color to paint, stucco, plaster, mortar, cement and linoleum. It must be fine, substantially insoluble and inert in the vehicle used.

The covering power of face powder is often imparted by the ZnO in the cosmetics. A typical face powder will often contain 20 percent zinc oxide.

PLANTS UTILIZING OXIDIZED CONCENTRATES

A new plant for the manufacture of zinc oxide by the direct flash fuming of zinc concentrates was completed and put in operation by the Eagle-Picher Mining and Smelting Company at Galena, Kansas in 1941.(19)

The addition of a slag fuming plant for recovering zinc from oxidized zinc ore at the Tooele (Utah) plant of the International Smelting and Refining Company has offered a new market to some Nevada miners.

METHODS OF BENEFICIATING OXIDIZED ZINC ORES

Gravity concentration methods are used for concentrating coarsely disseminated oxidized zinc ores. The recovery of the fine sizes of zinc mineral are therefore limited.

In the Highland, Wisconsin district small deposits of mixed carbonate and sulfide ore are worked by lessees. The ore is hand picked

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(18) Emery, Alden H. Mineral Fillers. Industrial Minerals and Rocks. A.I.M.E. N. Y. p. 493. 1937.

(19) Meyer, H. M. and Mitchell, A. W. Lead and Zinc Pigments and Zinc Salts. Minerals Yearbook. 1941. United States Bureau of Mines. p. 172.

and the high-grade material crushed in rolls, roughly concentrated in a log washer and cleaned with jigs. The mixed concentrates carry about 40 percent zinc. Recovery is low but deposits are too small to warrant more elaborate equipment.(20)

The New Jersey Zinc Company at Franklin, New Jersey beneficiates an ore containing willemite, franklinite and zincite and a calcite gangue.(21) The plant has a capacity of 1,640 tons a day. It makes a magnetic and gravity separation of a franklinite concentrate containing 17 percent zinc, a willemite-zincite concentrate containing 47 percent zinc, and a tailing of 1.25 percent zinc. The ore is concentrated by magnetic separation, jigging and tabling. This method works very well as the ore is coarsely disseminated.

At Montepone, Sardinia, a 500-ton plant treating calamine in dolomite with some zinc, lead and iron sulfides consists of a series of screens for preparing the feed for a picking belt, and a series of jigs. Concentrates and tailing are rejected at all sizes.(22)

The oxidized zinc ores utilized thus far have been the coarsely disseminated ores which can be concentrated by gravity or the high-grade ores which can be concentrated by gravity or the high-grade ores which can be concentrated by hand picking. The oxidized zinc ores that are finely disseminated are not amenable to concentration by gravity methods.

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(20) Lovering, T. S. Minerals in World Affairs. N. Y. Prentice Hall, 1943, p. 307.

(21) Taggart, Arthur F. Handbook of Mineral Dressing. N. Y. Wiley, 1945, pp. 163-166.

(22) Ibid.

Many of the zinc ores found are mixtures of sulfides and carbonate or silicate. One of the big commercial problems has been the occurrence of these mixed ores which are not amenable to gravity concentration methods used in the field. The general practice has been to keep the portions high in sphalerite separate from the rest if the mineral is unevenly distributed in a mine. It is marketed as a mixed ore at a considerably lower price than the carbonate or silicate.

As many of the oxidized zinc ores are finely disseminated the flotation process seems to be the more logical method of concentrating that portion of the ore which is of 48-mesh size or finer.

PRESENT METHODS OF FLOATING OXIDIZED ZINC ORES

A search through the published literature has brought out the fact that up to the present there are few reports of the successful concentration of the oxidized ores of zinc by flotation.

Gaudin says there has been no success in the treatment of oxidized ores of zinc by flotation, but that little work has been done toward the solution of the problem.(23) Gaudin however did some pioneering work on flotation of mixtures of zinc carbonate (contaminated with iron and manganese) with calcite by means of long chain xanthates and hydrosulfides, such as octyl xanthate, thiocresol, amyl mercaptan and heptyl mercaptan. His results showed that zinc carbonate can be collected from other carbonates by the use of certain chemical collectors. The amounts of reagents used ranged from 4 to 8 pounds a ton of feed. These quantities are excessively high and since the cost of the higher xanthate is appreciable it is doubtful if these reagents could be used because of economic reasons.

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(23) Gaudin, A. M. Flotation, pp. 315-316. McGraw-Hill, N. Y. 1932.

The Chemical Abstracts give a method by A. P. Andreeva in which smithsonite was floated by first giving it a preliminary sulfidization at 50° - 60° followed by flotation at room temperature. The review did not give the sulfidizing reagent that was used.(24)

Chemical Abstracts also report that a mixture of $ZnCO_3$ and $BaCO_3$ was separated by the use of 8-hydroxyquinoline as a collector in which terpineol was used as a frother. $ZnCO_3$ and SiO_2 mixtures and $PbCO_3$-SiO_2 mixtures were also reported separated with oxine.(25)

C. W. Davis reports the flotation of a calamine-cerussite ore in which the cerussite was first sulfidized with sodium sulfide and floated, after which the calamine was sulfidized with sodium sulfide, activated with copper sulfate and floated, producing a 47.8 percent zinc concentrate. The zinc concentrate represented 42.8 percent of the total zinc present from a fine-grained ore containing 26 percent zinc as calamine.(26)

DIFFICULTIES IN FLOATING SMITHSONITE

Most of the previous research work on the flotation of oxidized zinc minerals has been directed toward sulfidization and flotation with sulfide reagents. The zinc minerals have been difficult to sulfidize and hence difficult to float.

No investigations are recorded in which fatty acid collectors were used to float the oxidized zinc mineral, this line of attack was therefore regarded as more promising in investigating this problem.

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(24) Andreeva, A. P. Flotation of Smithsonite. Chemical Abstracts, 1942, p. 5447.

(25) Erlenmeyer, H. Steiger, J. V., and Theilheimer. Flotation Experiments with 8-Hydroxyquinoline as Collector. Chemical Abstracts, 1942, p. 5390.

(26) Davis, C. W. Calamine Ores. United States Bureau of Mines. Report of Investigation 3370, p. 99. 1938.

The common gangue minerals found with a zinc carbonate ore are calcite, dolomite, silica, and iron usually as hematite or limonite. Zinc carbonate mineral can be readily floated with a fatty acid such as oleic acid ($C_{17}H_{33}COOH$) or sodium oleate ($C_{17}H_{33}COONa$), the soap of oleic acid. The metallic soap forming at the surface of the smithsonite during flotation may be shown by the following reaction:

$$ZnCO_3 + 2C_{17}H_{33}COONa \rightarrow (C_{17}H_{33}COO)_2\ Zn + NaCO_3$$

Consequently the carbonate gangue present in the ore will be floated with the zinc carbonate mineral.

The problem can therefore be attacked in two ways:

1. Depress the smithsonite by the use of some reagent which will precipitate the zinc ions at the surface of the smithsonite so that a water repellent soap coating will not form when the fatty acid collector is used, in which instance the smithsonite would be depressed and the calcite floated.
2. Depress the calcium carbonate gangue by precipitation of the Ca-ions at the surface or by surface coating the mineral, so that a water repellent soap would not be formed; thus the zinc carbonate could be floated.

When floating the smithsonite, silica must be depressed. Silica is usually not readily floatable with the fatty acids used in flotation. However, the silica may have metallic ions adsorbed on the surface. These metallic ions will in turn cause the silica to float. In such cases it will be necessary to eliminate the Fe-ions at the silica surface by precipitation or surface coating prior to floating of the smithsonite with the fatty acid.

When floating the smithsonite the iron minerals present must also be depressed.

INVESTIGATION OF REX MINE ORE

Mineralogical Analysis

The mineralogical analysis of the ore was as follows:

Mineral	Chemical Composition	Amount Present
Chert	SiO_2	Large amount
Dolomite	$CaCO_3MgCO_3$	Large amount
Smithsonite	$ZnCO_3$	Large amount
Hemimorphite	H_2ZnSiO_5	Appreciable amount
Quartz	SiO_2	Appreciable amount
Iron oxides	Fe_2O_3	Small amount
Pyrite	FeS_2	Small amount
Sphalerite	ZnS	Very small amount

Chemical Analysis

The chemical analysis of the sample was as follows:

Substance	Analysis, Percent
Zinc (total)	20.3
Zinc (non-sulphide)	19.9
SiO_2	21.9
Insoluble	23.2
CaO	9.8
CO_2	22.5

FLOTATION TEST ON REX MINE ORE

A series of flotation tests were conducted on the Rex Mine ore to determine the effect of various starches and dextrins on the separation of the smithsonite and the carbonate gangue.

The sample was crushed in a laboratory jaw crusher to minus 3/8-inch. Quartering furnished a 20-pound sample which was further reduced in size by crushing in smooth rolls to minus 20-mesh, the rolls being in closed circuit with a 20-mesh screen. The minus 20-mesh sample was used for subsequent flotation tests. In the test work, 250-gram batches were ground in a pebble mill to minus 100-mesh, in stages of 5 minutes, using flint pebbles and zeolite-softened water. Flotation tests were conducted on the minus 100-mesh batches which were thickened to 25 percent solids and floated in a laboratory flotation cell of 250-gram capacity. The flotation cell used was of the mineral separation type, the sides and bottom of which were constructed of bakelite. Air was admitted at the bottom of the cell through an adjustable valve. Agitation was furnished by an impeller driven by an electric motor.

Reagents Used

Sodium Fluoride Fluoride ion precipitates the earth metals, ferrous and ferric ions. Therefore, sodium fluoride was used to precipitate any of these ions which may have been adsorbed at the surface of the chert and silica and to depress the iron oxide minerals.

Starches and Dextrins Starches and dextrins are carbohydrates which have the property of precipitating their miscelles on solid surfaces. The precipitating of the starch or dextrin may be selective on some surface, in which instance the surface coated would resist collector coating and would be depressed.

Sodium Oleate Sodium oleate was used as the collector and frother in all of the tests.

Preliminary Flotation Tests

Preliminary flotation tests were made to determine the depressing effect of starches and dextrins in depressing the carbonate gangue. For example, the pulp was first conditioned for 5 minutes using 1.0 pound of sodium fluoride a ton of ore. The second conditioning period was for 5 minutes using 1.0 pound of 132 Eagle pearl starch from the Corn Products Refining Company, New York. A rougher concentrate was floated using 0.1 pound of sodium oleate a ton of ore. Subsequently a second and a third rougher concentrate was floated using 0.1 pound of sodium oleate for each rougher concentrate floated.

The three rougher concentrates and the tailing were analyzed for zinc and carbon dioxide.

Other causticized starches and dextrins used in this series of flotation tests are as follows: 152 Dextrin, 185/30 Amijel, 186 Mogul brand cereal binder, 52 Hydrol, 126 Buffalo starch, and 150 Dextrin.

Analysis of the percent zinc and carbon dioxide in each rougher concentrate for each starch or dextrin investigated has been plotted in Figure 2.

Conclusion of Preliminary Tests

The causticized starches and dextrins investigated gave some depressing action on the smithsonite.

Causticized 152 Dextrin depressed smithsonite more than the other starches and dextrins investigated. Results of this test are tabulated in Table III.

Table III. Results of Flotation Test

Product	Weight, Percent	Analysis, Percent		Recovery
		Zn	CO_2	Zn
First rougher concentrate	12.1	15.7	37.4	9.1
Second rougher concentrate	15.8	17.2	34.9	13.0
Third rougher	12.2	17.8	32.7	10.4
Tailing	59.9	23.5	13.5	67.5
Composite	100.0	20.9	22.1	100.0

Final Flotation Tests

Preliminary flotation investigation of the depressing effect of starches and dextrins on smithsonite indicated that causticized 152 Dextrin or 150 Dextrin were the most effective in depressing the smithsonite. Two final tests were conducted using the causticized 152 Dextrin and 150 Dextrin. The procedure used was as follows:

The pulp of 25 percent solids and of minus 100-mesh grain size was conditioned with 1.0 pound of sodium fluoride a ton of ore and with 1.0 pound of causticized 152 Dextrin, sodium oleate equivalent to 0.3 pound a ton of ore was used to float a rougher carbonate gangue concentrate. This rougher concentrate was cleaned 2 times. Tailings were combined with the middling and the slimes decanted. The deslimed pulp was repulped in the 250-gram flotation cell and a rougher zinc concentrate floated using 0.8 pound of oleic acid a ton of ore. The zinc concentrate was cleaned 3 times. Results of the test are tabulated in Table IV.

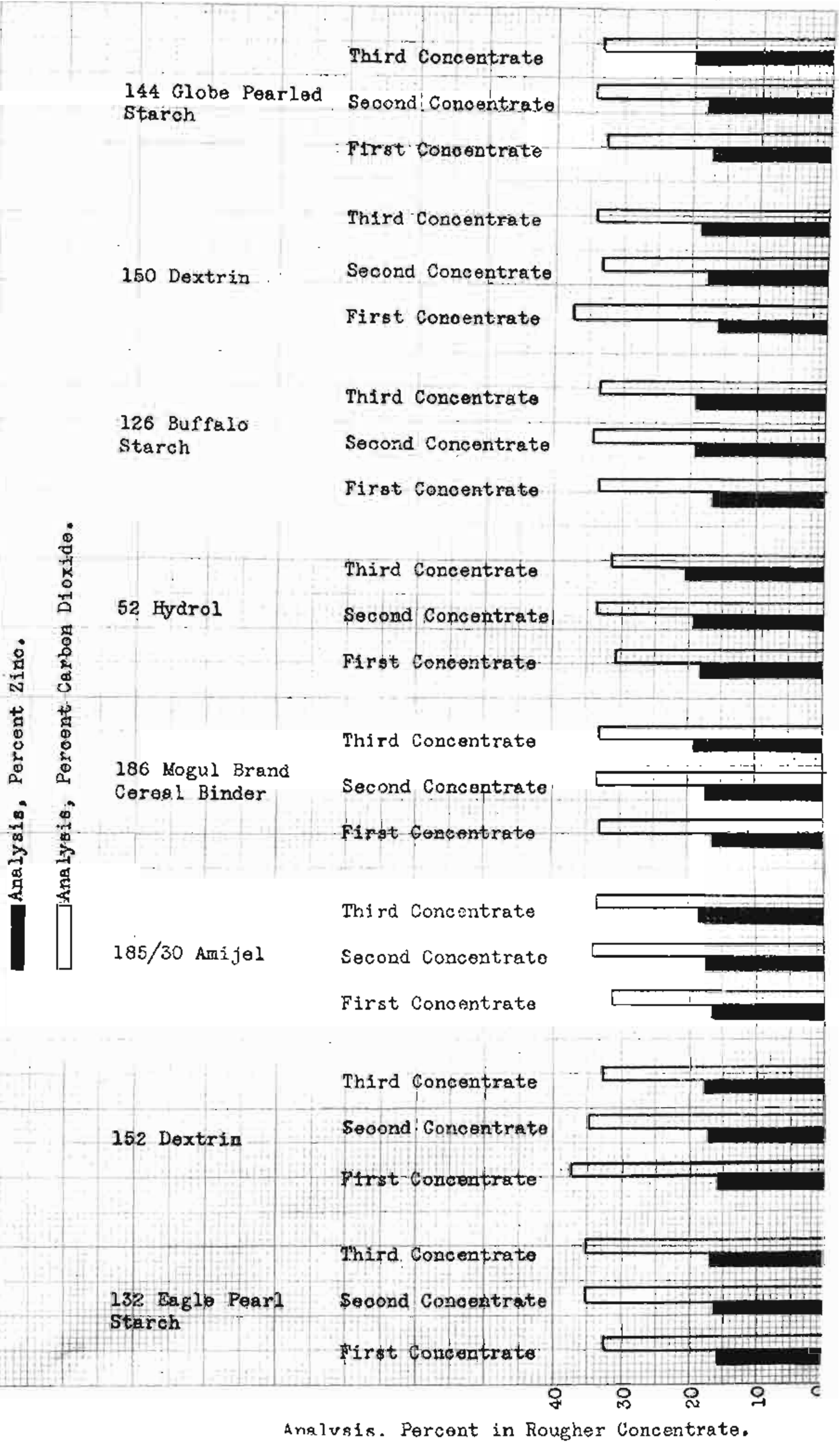
Table IV. Results of Flotation

Product	Weight, Percent	Analysis, Percent		Recovery, Percent
		Zn	CO2	Zn
Carbonate gangue concentrate	10.6	16.2	41.1	8.0
Zinc concentrate	45.8	21.6	31.6	46.2
Zinc middling	13.8	23.6	6.5	15.2
Slimes	5.3	22.5	10.2	5.6
Tailing	24.5	21.9	4.0	25.0
Composite	100.0	21.4	21.8	100.0

Conclusions of Final Flotation Tests

The causticized 150 and 152 Dextrin gave some depression of zinc carbonate, as a result larger amounts of carbonate gangue were floated.

Figure 2. Analysis Percent of Zinc and Carbon Dioxide in Rougher Concentrates.



The depressing action of 150 and 152 Dextrin was not positive enough to produce a carbonate gangue concentrate of low zinc content. The carbonate concentrate assayed 16.2 percent zinc.

Zinc concentrates assayed only 21.6 percent zinc and contained a large amount of carbonate gangue.

Zinc middlings contained 23.6 percent zinc and 6.0 percent carbon dioxide. The conclusion is that the middling contains a small amount of carbonate gangue and smithsonite and a large amount of hemimorphite.

The tailings assayed 21.9 percent zinc and 4.0 percent carbon dioxide. The majority of the zinc is evidently present as hemimorphite.

Flotation tests were discontinued on the Rex Mine ore. It was believed that more pertinent information on the depressing effect of various reagents, on smithsonite as carbonate gangue, would be found if the investigation were conducted on an ore which contained the zinc as smithsonite only.

INVESTIGATION OF ALICE MINE ORE

Composition of Ore

Mineralogical Analysis

The ore consisted of cross fracture weathered chert containing a large amount of smithsonite and dolomite, and appreciable content of sphalerite, a small amount of iron oxides as hematite and limonite, a small amount of pyrite and quartz, and a very small amount of hemimorphite and clay.

The smithsonite occurred in fracture as fillings or incrustations, as fillings and cementing material in brecciated zones and in irregular openings. Smithsonite varies from firm clean areas to soft admixtures with iron oxides and dolomite. Many fractures were filled with iron oxides as hematite or oxidizing to limonite and most of the pyrite is associated with these areas. Chert areas are in varying stages of weathering with some zones approaching tripoli.

Chemical Analysis

Chemical analysis of the Alice Mine is as follows:

Analysis, Percent

Zinc						
Total	Non-sulfide	SiO_2	CaO	Fe	CO_2	Insoluble
22.9	22.7	21.3	3.8	8.1	22.3	22.6

Float-and-Sink Test

Use of a heavy liquid was made to separate the smithsonite from the chert and carbonate gangue in order that the characteristics of the ore could be studied. It offered a means of determining the degree of liberation of the valuable minerals, at various sizes, and the feasibility of gravity concentrating the ore.

A portion of the ore sample was sized as shown in Table V.

Acetylene tetrabromide of specific gravity 2.92 was used to dissect each screen size into a float and a sink product.

Table V. Float-and-Sink Test

Size	Product	Weight, Percent	Analysis, Percent		Recovery, Percent Zn
			Zn	Fe	
Minus 3 plus 4-mesh	Float on 2.92	35.59	6.77	-	11.13
	Sink in 2.92	64.41	29.88	17.1	88.87
		100.00	21.65		100.00
Minus 4 plus 10-mesh	Float on 2.92	36.65	5.35	-	9.58
	Sink in 2.92	63.35	29.16	16.7	90.41
		100.00	20.43		100.00
Minus 10 plus 20-mesh	Float on 2.92	37.97	4.69	-	8.69
	Sink in 2.92	62.03	30.15	13.6	91.31
		100.00	20.41		100.00
Minus 20 plus 35-mesh	Float on 2.92	18.70	3.28	-	2.33
	Sink in 2.92	81.30	31.68	15.5	97.67
		100.00	26.37		100.00
Minus 35 plus 65-mesh	Float on 2.92	18.96	3.06	-	2.18
	Sink in 2.92	81.04	32.16	13.8	97.82
		100.00	26.64		100.00
Minus 65 plus 200-mesh	Float on 2.92	26.52	2.84	-	2.96
	Sink in 2.92	73.48	33.64	10.5	97.04
		100.00	25.47		100.00

Benzene was used as the washing agent. Analyses of zinc were made on each product and analyses for iron were made on the sink products only. The float products were relatively free from iron as was characterized by the light color of the product.

Conclusion of Float-and-Sink Test

The precent of zinc locked in the chert and carbonate gangue at size minus 20 plus 35-mesh is 3.28 percent, at size minus 65 plus 200-mesh is 2.84 percent. Grinding the ore finer than minus 35-mesh would not increase the amount of recoverable zinc appreciably.

Large amounts of iron were present in the sink products, hence gravity concentration methods would probably fail to give a high-grade zinc concentrate. This subject will be later referred to in the discussion on the tabling test.

PRELIMINARY FLOTATION TESTS

The ore sample was crushed in a laboratory jaw crusher to minus 3/8-inch. After primary crushing the ore was reduced in size to minus 20-mesh by crushing in smooth rolls. Batches of 250 grams were stage ground in a pebble mill to minus 100-mesh using flint pebbles and zeolite-softened water. The ground ore after filtering was repulped to 25 percent solids and floated in a 250-gram laboratory flotation cell.

Causticized 152 Dextrin had given some depressing action on smithsonite in the Rex Mine ore experiments. Therefore a series of tests was conducted on the Alice Mine ore to determine the depressing affect of the following reagents when used with the causticized 152 dextrin: Sodium hydroxide ($NaOH$), sodium pyrophosphate ($Na_4P_2O_7$), tri-sodium phosphate (Na_3PO_4) calgon ($(Na_6(PO_3)_6$, sodium silicate ($Na_2O \cdot SiO_2$) and sodium fluoride (NaF).

Procedure of Preliminary Tests

The minus 100-mesh ground batches were thickened to 25 percent solids and conditioned with 1.0 pound of the reagent to be tested and with 1.0 pound of causticized 152 Dextrin a ton of ore. A rougher concentrate was floated using 0.05 pounds of sodium oleate a ton of ore. After the first rougher concentrate a second rougher concentrate was removed with an additional 0.05 pounds of sodium oleate a ton of ore. In like manner a third rougher concentrate was floated.

Results of the flotation test are shown in Figure 3 where the percent recovery of zinc and calcium carbonate in each rougher concentrate have been recorded.

Discussion of Flotation Results

In all of the tests the zinc was being depressed in the first rougher concentrates that were floated.

Calgon began to depress the carbonate gangue in the second rougher concentrate. Sodium silicate is the only reagent tested which was not depressing the carbonate gangue in floating of the third rougher concentrate.

Conclusions

The following reagents - sodium hydroxide, tri-sodium phosphate, calgon, sodium silicate, and sodium fluoride - when used with causticized 152 Dextrin either reverse their depressing effect on smithsonite or else their depressing effect becomes almost nil. These chemicals show no promise of being satisfactory reagents for the separation of the smithsonite and carbonate gangue by flotation.

Investigation of Other Reagents

Tannins and Dyewoods

Tannin and dyewood extracts are now prepared from nearly all of the tannin substances by extracting with water in specially designed extracting equipment and then evaporating the tannin solution to a thick syrup or even to dryness. These products contain from 25 to 60 percent of tannin and are precipitated when they come in contact with metallic salts. The composition of some of the extracts produced are unknown.

The following tannins and dyewoods from the American Dyewood

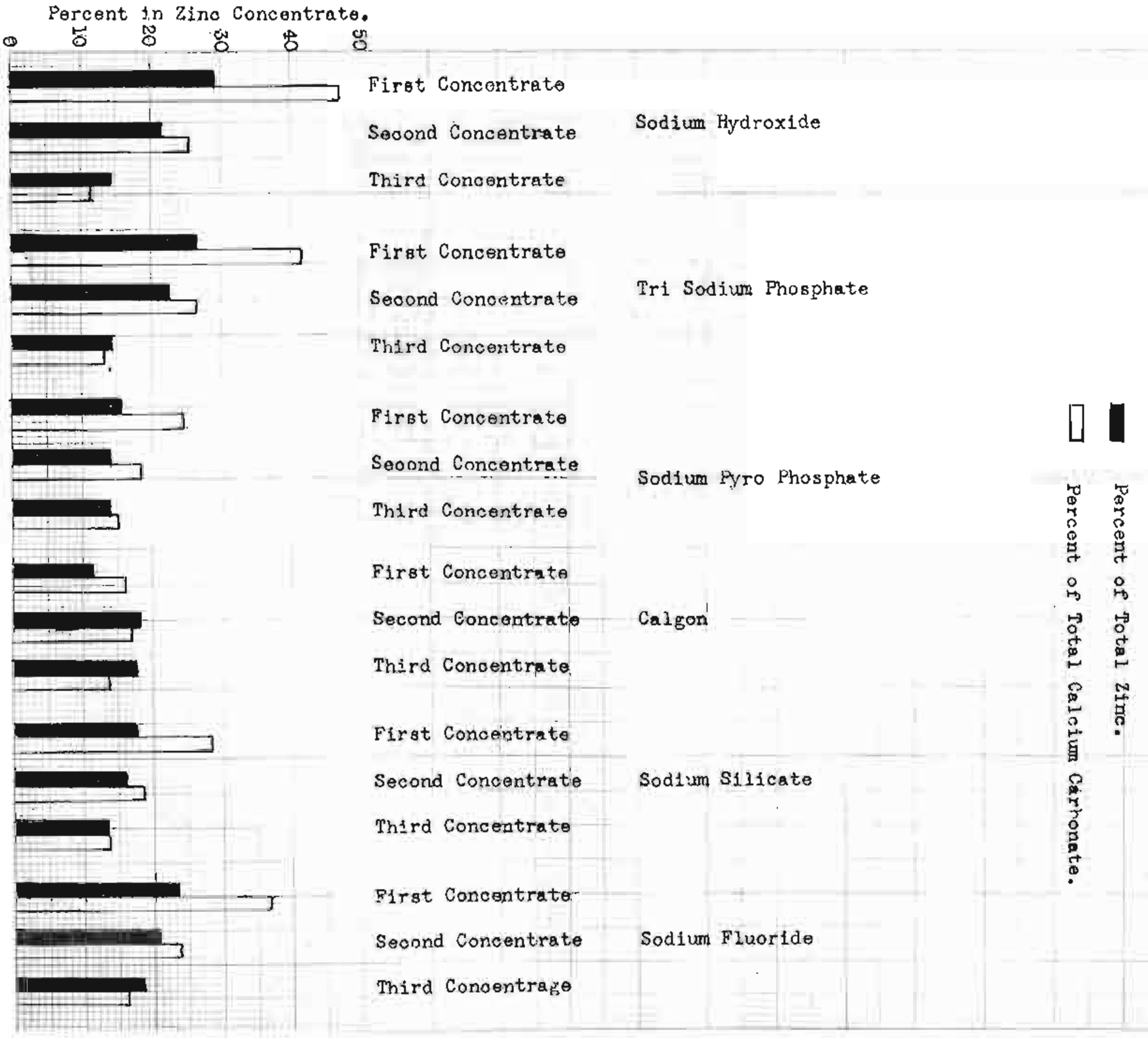


Figure 3. Percent of Total Zinc and Calcium Carbonate in Rougher Concentrate.

Company, New York, were tested for their depressing effect on smithsonite or carbonate gangue, wattle extract, logwood extract No. 2, chestnut extract, sumac extract, hypernic extract No. 3, divi-divi extract, quecritron extract, fustic extract No. 3, and osage orange extract.

Daxads

Daxads are polymerized organic salts of sulfonic acid and are dispersing agents. Two reagents from the Dewey and Almy Chemical Company, Massachusetts, were tested: Daxad No. 11 and Daxad No. 23. Daxad No. 23 may act as a protective colloid for the purpose of coating solid particles.

Synthetic Tannin Reagents

Exan, a synthetic tannin reagent containing 26 to 28 percent tannin and Mertanol 7L, a syntan having a tannin content of 19 to 20 percent from the Merrimac Division of Monsanto Chemical Company, Everett, Massachusetts were also investigated.

Lignin Sulphonate Reagents

Lignin sulphonates are salt from the lignin constituent of sulphite pulp mill liquors, and are commercially available as the salts of most metals. The structural composition of the lignin sulphonates has not been fully established. The chemical characteristics of the lignins include dispersing, ion exchange and absorption properties. Marathon DT-III-6, and Marathon magnesium lignin sulphonate from the Marathon Chemical Company, Rothschild, Wisconsin and Horn-Kem No. 101 from the Horn-Kem Corporation, New York were used in preliminary testwork.

8-hydroxyquinoline

8-hydroxyquinoline from the Monsanto Chemical Company, St. Louis, Missouri, was investigated for its effect in the separation of smithsonite and carbonate gangue.

Acids

Malic acid (C4H6O5), citric acid ($C_6H_8O_7$) and tartaric acid ($C_4H_6O_6$) were investigated for their depressing effect on smithsonite or carbonate gangue.

Preliminary Flotation Procedure

Batches of 250-gram of ore were ground in stages of 5 minutes to minus 100-mesh in a pebble mill using flint pebbles and zeolite-softened water. The pulp of 25 percent solids was in each test conditioned for 5 minutes with 1.0 pound of sodium fluoride a ton of ore and for 5 minutes with one of the following reagents: Wattle extract, logwood extract No. 2, Chestnut extract, sumac extract, hypernic extract No. 3, divi-divi extract, quercritron extract, fustic extract No. 3, osage orange extract, Exan 930, Mertanol 7L, Marathon DT-III-6, Marathon magnesium lignin sulphonate, Horn Kem No. 101, 8-hydroxyquinoline, malic acid, citric acid, and tartaric acid. A rougher concentrate was floated using 0.1 pound of sodium oleate a ton of ore. After removing the first rougher concentrate from the flotation cell, a second and finally a third rougher concentrate were floated using 0.1 pound of sodium oleate as collector and frother for each rougher concentrate removed from the cell.

Results and Conclusions of Preliminary Tests

Figure 4 gives a comparison of the percent recovery of zinc and calcium carbonate in each rougher concentrate for each reagent investigated.

The only reagent tested which depressed the calcium carbonate in

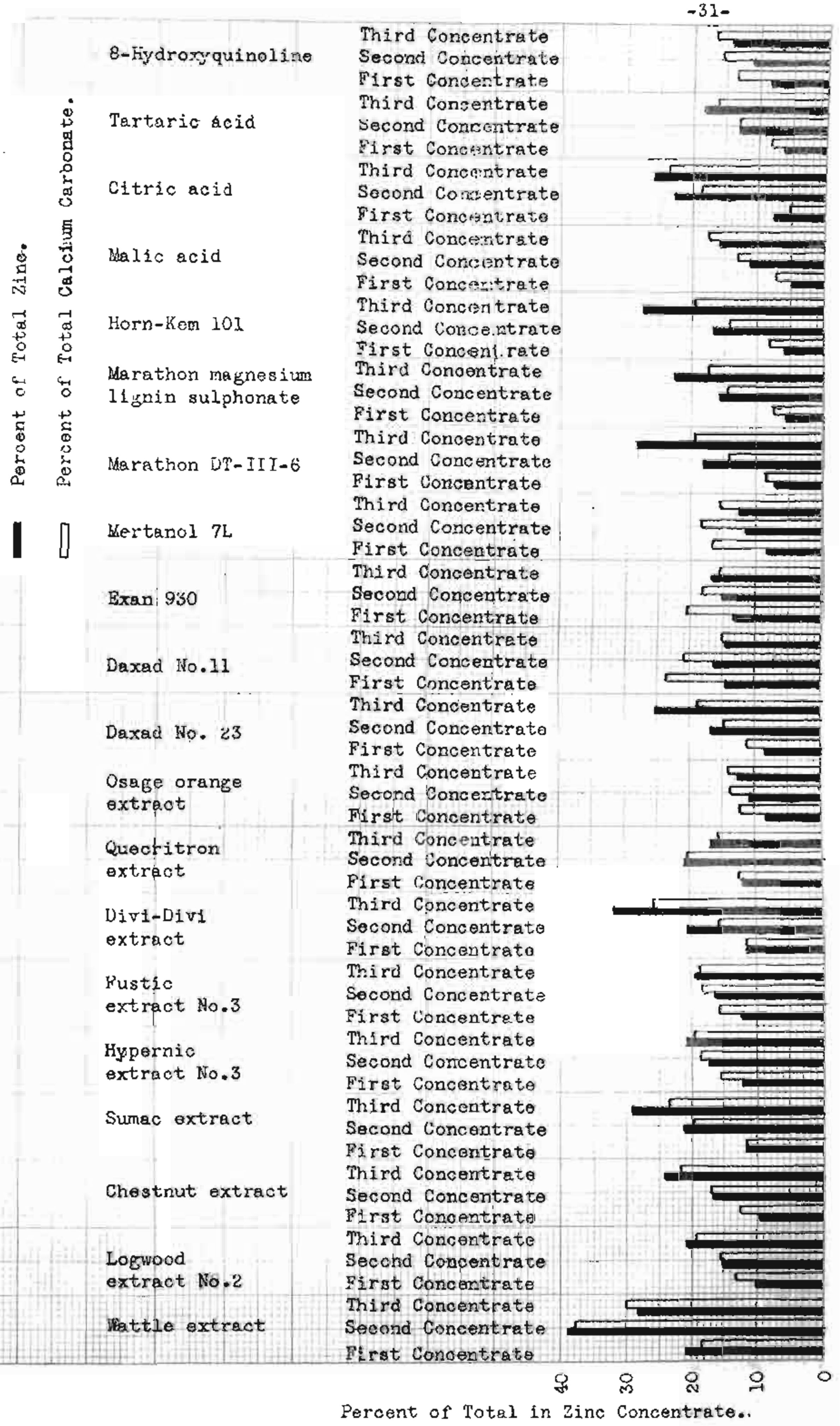


Figure 4. Percent of Total Zinc and Calcium Carbonate in Rougher Concentrates.

all three rougher concentrates was citric acid. All other reagents tested either depressed the smithsonite in some of the rougher concentrates and calcium carbonate in others.

The depressing effect of citric acid on calcium carbonate appeared great enough to justify further investigation.

Effect of Citric Acid Concentration when used with Sodium Fluoride

In these tests the pulp of 25 percent solids was conditioned with 1.0 pound of sodium fluoride a ton of ore and with a concentration of citric acid as shown by Figure 5. A rougher zinc concentrate was floated using 0.8 pound of sodium oleate a ton of ore. The rougher concentrate was cleaned 4 times.

Figure 5 gives a comparison of the assay percents of zinc and calcium carbonate, it also compares the percent recovery of zinc and calcium carbonate for the various tests.

A large concentration of citric acid results in the production of zinc concentrate containing less calcium carbonate, this zinc concentrate contains 40.9 percent of the total calcium carbonate.

Effect of Sodium Silicate Concentration

The citric acid and sodium hydroxide concentration used in these series of tests was 1.0 pound each a ton of ore. The concentration of sodium silicate was varied from 0.0 to 2.0 pound a ton of ore. The rougher concentrate removed in each test was floated with 0.8 pound of sodium oleate a ton of ore. Each rougher concentrate was cleaned 4 times.

Figure 6 compares the assay percent and recovery percent of zinc and calcium carbonate for each test. The maximum zinc recovery was obtained when using a sodium silicate concentration of 1.0 pounds a

Figure 5. Assay and Recovery Percent of Zinc and Calcium Carbonate in the Zinc Concentrates.

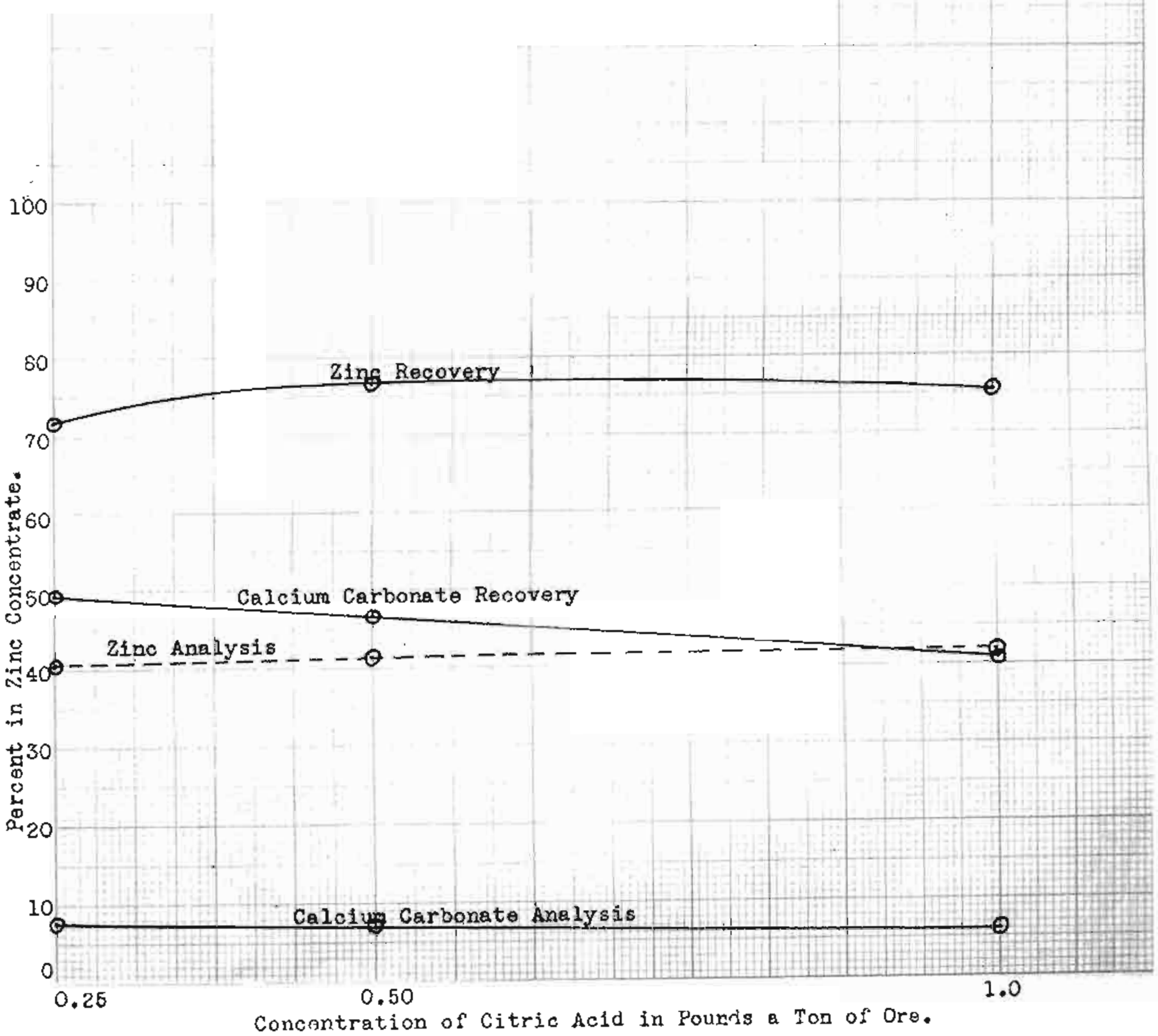
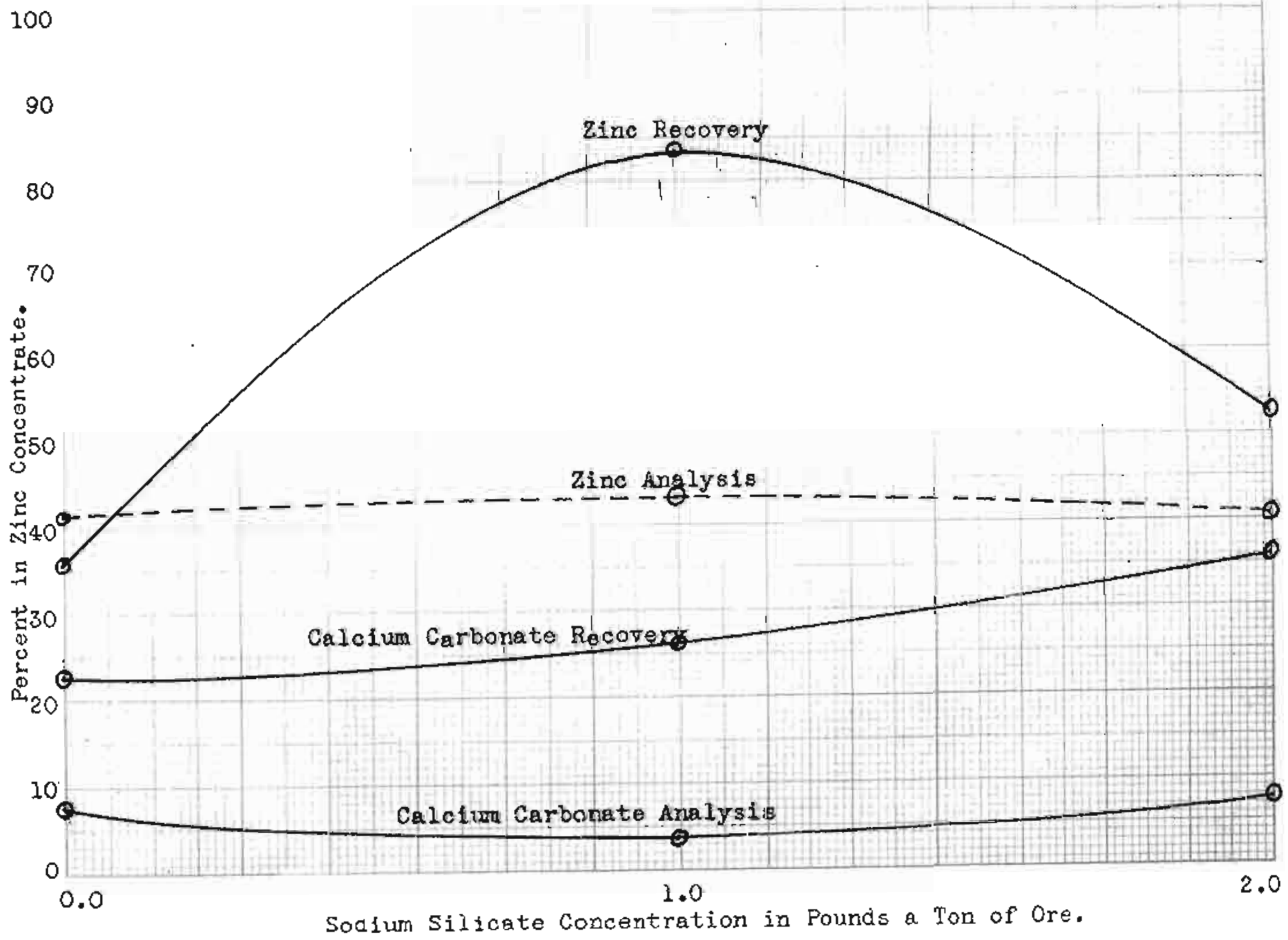


Figure 6. Assay and Recovery Percent of Zinc and Calcium Carbonate in the Zinc Concentrates.



ton of ore. This concentration of sodium silicate also produced a zinc concentrate containing the minimum assay percent of calcium carbonate. At a sodium silicate concentration of 0.0 pound and 2.0 pounds a ton of ore the recovery of zinc decreases appreciably and the calcium carbonate present in the zinc concentrate increases.

Effect of Sodium Hydroxide Concentration

Flotation tests were conducted using a citric acid concentration of 1.0 pound a ton of ore and sodium silicate concentration of 1.0 pound a ton of ore. The concentration of sodium hydroxide used for each test is given in Figure 7. The rougher concentrate was floated using 0.6 pound of sodium oleate a ton of ore. Each rougher concentrate was cleaned 3 times.

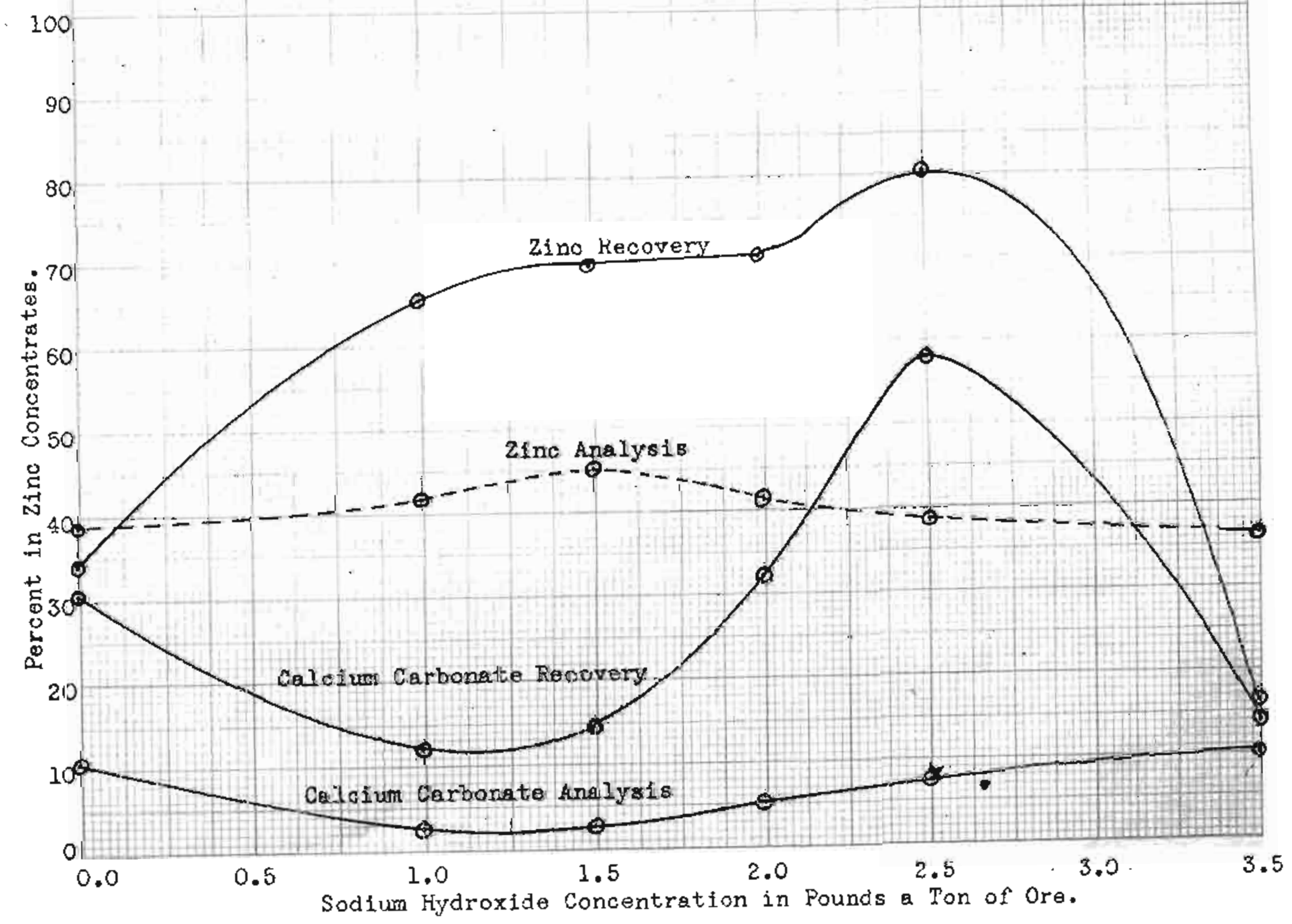
From Figure 7 it can be seen that the concentration of sodium hydroxide is critical. This means that the pH of the pulp must be controlled within certain limits for producing a satisfactory smithsonite concentrate.

A sodium hydroxide concentration of 1.0 to 1.5 pounds a ton of ore corresponds to a pH range of from 8.5 to 9.0.

The highest grade of zinc is obtained when sodium hydroxide concentrations of 1.0 to 2.0 pounds a ton of ore is used. This concentration of sodium hydroxide gives a zinc concentrate containing the least calcium carbonate.

It is interesting to note how the recovery increases at a sodium hydroxide concentration of 2.5 pounds a ton of ore. However, at this concentration of sodium hydroxide the calcium carbonate is no longer being depressed as well as it had been at lower concentrations of sodium hydroxide.

Figure 7. Assay and Recovery Percent of Zinc and Calcium Carbonate in the Zinc Concentrates.



Effect of Citric Acid Concentration

In the tests in which citric acid concentration was varied the samples were ground, as before, to minus 100-mesh, thickened to 25 percent solids and conditioned with 1.0 pound of sodium hydroxide and 1.0 pound of sodium silicate a ton of ore. The pulp was conditioned with citric acid concentrations as shown in Figure 8, where the results of the various tests have been plotted.

The assay percent of zinc in the concentrates increases from 43.0 percent to 44.5 percent as the citric acid concentration is increased from 0.5 pound to 2.0 pounds a ton of ore.

The assay percent of calcium carbonate in the zinc concentrates is a maximum of 5.2 percent at a citric acid concentration of 0.5 pound a ton of ore, it is a minimum of 2.6 percent as a citric acid concentration of 2.0 pounds a ton of ore.

The recovery of calcium carbonate decreases from 29.1 percent at a citric acid concentration of 0.5 pound a ton of ore to 16.6 percent when a citric acid concentration of 2.0 pounds a ton of ore was used.

Maximum zinc recovery was obtained at a citric acid concentration of 1.0 pound a ton of ore.

Conclusions of Chemical Reagents Tested

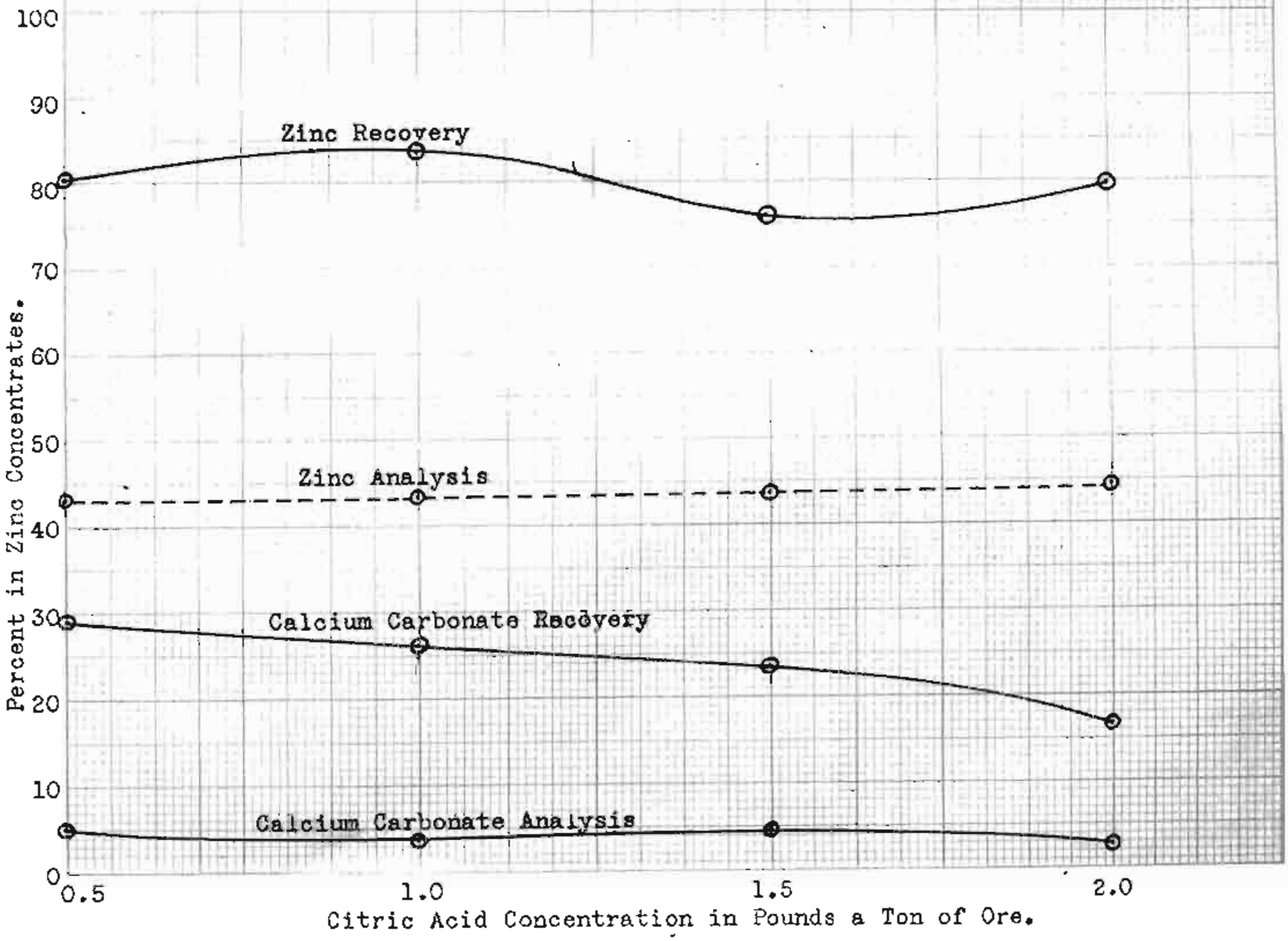
Citric acid was the most effective reagent tested in depressing the carbonate gangue.

Sodium hydroxide was used to give the pulp a pH that would give the optimum separation of smithsonite and carbonate gangue.

Sodium silicate was effective in dispersing the pulp and depressing the silica, chert and iron.

The zinc concentrate of highest grade was produced, when the minus

Figure 8. Assay and Recovery Percent of Zinc and Calcium Carbonate in the Zinc Concentrate.



100-mesh ore batch was thickened to 25 percent solids and conditioned with 1.0 pound of sodium hydroxide, 1.0 pound of sodium silicate, and 2.0 pounds of citric acid a ton of ore. Sodium oleate equivalent to 0.8 pound a ton of ore being used for floating the rougher concentrate. Four cleanings of the rougher concentrate were required to produce a zinc concentrate containing 44.5 percent zinc.

The results of the test producing the highest grade of zinc concentrate has been tabulated in Table VI.

Table VI. Results of Flotation

Product	Weight, Percent	Analysis, Percent				Percent of Total			
		Zn	$CaCO_3$	Fe	Insol.	Zn	$CaCO_3$	Fe	Insol.
Zinc concentrate	41.0	44.5	3.9	1.2	3.5	79.9	19.9	5.2	6.7
Zinc middling	27.6	12.2	20.4	7.3	19.6	14.7	70.3	21.3	25.2
Tailing	31.4	3.9	2.5	22.1	46.6	5.4	9.8	73.5	68.1
Composite	100.0	22.8	8.0	9.4	21.5	100.0	100.0	100.0	100.0

The maximum recovery of zinc in the smithsonite concentrates was produced when the minus 100-mesh ore sample was thickened to 25 percent solids and conditioned with 1.0 pound of sodium hydroxide, 1.0 pound of sodium silicate, and 1.0 pound of citric acid a ton of ore. The rougher concentrate was floated using 0.8 pound of sodium oleate a ton of ore. The rougher concentrate was cleaned four times. The zinc concentrate produced contained 43.5 percent zinc which represented 83.6 percent of the total zinc. Results of this flotation test have been tabulated in Table VII.

Table VII. Results of Flotation Test

Product	Weight, Percent	Analysis, Percent			Percent of Total		
		Zn	$CaCO_3$	Fe	Zn	$CaCO_3$	Fe
Zinc concentrate	44.8	43.5	3.7	1.0	83.6	26.1	5.6
Zinc middling	34.3	8.6	13.1	10.8	12.6	70.6	46.3
Tailing	20.9	4.2	1.0	18.4	3.8	3.3	48.1
Composite	100.0	23.3	6.4	8.0	100.0	100.0	100.0

The flotation results show that a zinc concentrate of satisfactory grade and of good recovery has been produced.

Tabling Test

The sink-and-float analysis had indicated that the ore from the Alice Mine could not be satisfactorily concentrated by gravity methods. The ore contained 8.1 percent of iron as limonite and hematite and the difference between the specific gravity of the smithsonite and these iron oxides is not large enough to give a good gravity separation. However it was felt that it might be possible to reject a low-grade tailing and provide an enriched feed for flotation.

A seventeen-pound sample of minus 20-mesh ore was classified in a 5-1/2-inch by 30-inch constriction-plate hydraulic classifier into a slime and three spigot discharge products.

Each spigot discharge product was subjected to a table test. The table used was a 24 by 48 inch diagonal deck concentrator manufactured by the Diester Concentrator Company.

The table concentrate from each spigot discharge was retabled producing a final concentrate and middling. These middlings were combined and crushed to minus 35-mesh. The middlings were retabled producing a fourth zinc concentrate, a final middling and a tailing. In Table VIII are recorded the results of the tabling test.

Conclusions from Tabling Test

The table concentrate from spigot discharge 3 was the only concentrate produced of a satisfactory zinc grade. This concentrate contained only 6.3 percent of the total zinc.

Considering all of the zinc concentrate products as a combined product, the zinc concentrate produced would assay 34.3 percent zinc, and would represent 76.5 percent of the total zinc.

Although the table did effect a considerable amount of beneficiation, the net result was unsatisfactory. The table tailing contained more zinc than the flotation tailing, hence no advantage would be gained by using the table as a preconcentrating device prior to flotation.

FINAL SUMMARY AND CONCLUSIONS

Various reagents such as starches, dextrins, natural tannin extracts, dyewood extracts, synthetic tannins, daxads, lignin sulphonates, 8-hydroxyquinoline, malic acid, citric acid, and tartaric acid were investigated to determine their depressing effect on smithsonite or carbonate gangue.

It was found that citric acid was the most effective reagent in depressing carbonate gangue and permitting the rapid flotation of smithsonite.

Table VIII. Results of Table Test

Product	Weight, Percent	Analysis, Percent		Recovery, Percent	
		Zn	Fe	Zn	Fe
Spigot 1					
Concentrate	36.9	33.1	14.7	98.4	98.6
Tailing	2.3	8.5	3.4	1.6	1.4
	39.2	31.6	14.0	100.0	100.0
Spigot 2					
Concentrate	9.7	35.9	10.8	87.5	82.5
Tailing	6.7	7.4	3.3	12.5	17.5
	16.4	24.2	7.7	100.0	100.0
Spigot 3					
Concentrate	3.7	41.9	5.1	89.9	66.4
Tailing	2.9	6.0	3.3	10.0	33.6
	6.6	26.1	4.3	100.0	100.0
Reground middling					
Concentrate	4.5	35.6	13.5	69.1	60.9
Tailing	6.5	11.0	5.9	30.9	39.1
	11.0	21.1	8.9	100.0	100.0
Zinc concentrate	54.8	34.3	13.1	76.5	76.3
Zinc middling	4.2	25.2	13.8	4.3	5.8
Tailing	18.4	8.6	4.3	6.4	8.2
Slimes	22.6	13.9	4.1	12.8	9.7
Composite	100.0	24.6	9.5	100.0	100.0

Additional testwork on the effect of pH and concentration of citric acid and sodium silicate produced a zinc concentrate of satisfactory grade and recovery. The concentrate containing the highest grade of zinc, assayed 44.5 percent zinc and contained 79.9 percent of the total zinc. The largest recovery was obtained in a test which contained 83.5 percent of the total zinc and assayed 43.6 percent zinc.

Specific dissection of the ore with a heavy liquid and table test showed that the iron present as hematite and limonite prevents the production of a satisfactory grade of zinc by gravity concentration.

The tabling concentrate produced contained only 34.3 percent zinc which represented 76.5 percent of the total zinc.

This investigation indicates that flotation would be a better method for concentrating the smithsonite ore from the Alice Mine than would gravity methods of concentration.

Shortage of time did not permit the investigation of concentrating of hemimorphite by flotation as had originally been planned.

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INDEX