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ZINC

BY P. E. JOSEPH

Introduction:—
Because of the fact that the greatest zinc smelting centres of the world outside of the United States are located in the war zone of Europe, the effect of the war on the spelter market has been most pronounced. The European smelters have either been forced to suspend operations or, if able to operate, their product has not been able to reach the outside world. Owing to this, both the zinc smelting and the zinc mining industries of the United States have enjoyed a year of unparalleled prosperity in 1915. According to the latest information, the recoverable zinc content of zinc ores mined in the United States in 1915 was over 560,000 short tons, compared with 407,000 tons in 1914 and 418,000 tons in 1913. With a continuance of high prices of spelter during 1916, the output will be greatly augmented, for the very high prices did not begin until April and May, and it was naturally some time before additional zinc mining could get under way.

ORES OF ZINC

The important ores of zinc are sphalerite, smithsonite, and calamine, and in New Jersey willemite, zincite and franklinite occur in quantity sufficient to be considered ores.

SPHALERITE—ZINC BLEND—BLACK JACK

Composition: A sulphide of zinc (ZnS), often containing cadmium, manganese, and iron. Pure sphalerite contains 67 per cent zinc and 33 per cent sulphur.

General Description: Sphalerite is a mineral of resinous lustre, shading in color from yellow through brown to nearly black, and is transparent to opaque. In structure it is frequently cleavable massive, but also in crystals and in compact fine grained masses or alternate concentric layers with galenite.

Physical Characteristics:
Hardness, scratched by knife (3.5-4) Sp. Gr. (3.9-4.1) Moderately heavy.
Lustre, resinous. Transparent to translucent.
Streak, white to pale brown. Tenacity, brittle.
Color, yellow, brown, black; rarely black, green or white.
Qualitative Tests: On charcoal fuses with difficulty, but readily yields a sublimate, sometimes brown at first from cadmium, and later yellow-white hot, white, cold, and becoming bright green if moistened and ignited with cobalt solution. If heated with soda on charcoal, the residue moistened and placed on silver coin, it will stain the coin—test for sulphur. Soluble in hydrochloric acid with effervescence of hydrogen sulphide, which has a smell of rotten eggs.

Sphalerite, when occurring in small crystals, is sometimes confused with garnet and cassiterite, but being much softer than either of the above, it is easily distinguished by testing for hardness.

Occurrence: Sphalerite is the most important ore of zinc and is an extremely common mineral, especially as a constituent of metallic veins. It is found widely distributed, but chiefly in veins and irregular bodies in limestone rocks. It is associated with other sulphides and other zinc ores, is a common constituent of lead and silver ores in which case it is a detriment, as it makes their treatment more difficult.

Sphalerite has probably been formed by precipitation from water by H₂S or with the aid of decaying organic matter.

SMITHSONITE—DRY BONE—CALAMINE

Composition: Zinc carbonate (ZnCO₃). The pure mineral contains 52.0 per cent zinc, but the zinc content is often replaced by iron and manganese, and sometimes calcium and magnesium.

General Description: A white vitreous mineral, often colored yellowish or brownish by iron. In structure it occurs stalactitic or botryoid or with drusy crystal surface; also in chalky, cavernous masses and granular. Sometimes colored deep green by copper and bright yellow by cadmium.

Physical Characteristics:
- Hardness, scratched by knife with difficulty. (5)
- Lustre, vitreous to dull. Translucent to opaque.
- Streak, white. Tenacity, brittle.
- Color, shades of white, more rarely yellow, green, blue, etc.

Qualitative Tests: Infusible, but on charcoal readily yields a white sublimate which becomes yellow when heated and bright green when moistened with cobalt solution and then heated. Soluble in acids with effervescence.
Smithsonite is distinguished from calamine by effervescence with acids, and from other carbonates by its hardness.

**Occurrence:** Smithsonite is a secondary zinc ore formed usually by the action of carbonated waters on other zinc ores, and sometimes by the action of the atmosphere. It is found in connection with zinc deposits near the surface where the oxidized ores have been acted upon by carbonated waters, and is common with zinc deposits lying in limestone rocks. It is associated with sphalerite, galena, cerussite, calamine, calcite, limonite, etc.

**CALAMINE—ELECTRIC CALAMINE**

**Composition:** A hydrated zinc silicate, containing 54.2 per cent zinc.

**General Description:** A white or brownish white vitreous mineral, frequently with a drusy surface or in radiated groups of crystals, the free end of which form a ridge or cockscomb. Rarely in small, distinct, transparent crystals. Occurs also granular, stalactitic, botryoidal, and as a constituent of some clays.

**Physical Characteristics:**
- Hardness, scratched by knife with difficulty. Sp. Gr. (3.4-3.5) light to moderately heavy.
- Lustre, vitreous to pearly. Opaque to translucent.
- Streak, white. Tenacity, brittle.
- Color, yellow to brown, white, colorless, rarely blue or green.

**Qualitative Tests:** Fusible only in finest splinters. With soda or borax, on charcoal yields a white coating, which is made bright green by heating with cobalt solution. In closed tube yields water. Is soluble in acids with gelatinous residue.

**Occurrence:** Calamine is a mineral of secondary origin, formed, probably, by the action of hot silica bearing waters upon other zinc ores, especially sphalerite. It is found in the oxidized zone of zinc deposits, associated with smithsonite, sphalerite, cerussite, anglesite, galena, etc. It often occurs disseminated through a clay, from which it is gradually segregated and crystallized. Usually associated with limestone rocks, and its most important occurrence in the United States is with zinc deposits of southwestern Missouri and at Sterling Hill, near Ogdensburg, N. J.

**WILLEMITE—TROOSTITE**

**Composition:** Zinc silicate ($\text{Zn}_2\text{SiO}_4$), containing 58.5 per cent zinc, with manganese often replacing zinc. Iron also present at times in small amounts.
Arizona State Bureau of Mines

General Description: A greenish yellow to apple green or sulphur yellow mineral, when pure, but often flesh red or brownish from manganese or iron. Usually massive to granular. Rarely crystallized, except in the manganiferous variety.

Physical Characteristics:
- Hardness, scratched by knife
- Sp. Gr. (3.89-4.2) moderately with difficulty. (5.5) heavy.
- Lustre, resinous. Transparent to opaque.
- Streak, nearly white. Tenacity, brittle.
- Color, greenish to sulphur yellow; apple green, white, flesh red.

Qualitative Tests: In thin splinters fusible upon the edges to a white enamel. On heating with cobalt solution becomes blue. On charcoal with soda and a little borax yields a white coating. Soluble in hydrochloric acid leaving a gelatinous residue.

Occurrence: In the United States it is found at Franklin Furnace in association with franklinite and zincite. Occurs sparingly at Merritt Mine, N. M. Also found in Belgium.

ZINCITE—RED ZINC ORE

Composition: Zinc oxide (ZnO) containing 80.3 per cent zinc, with usually some manganese or iron replacing the zinc.

General Description: A deep red to brick-red adamantine mineral, occurring in lamellar or granular masses, either in calcite or interspersed with grains and crystals of black franklinite and yellow to green willemite.

Physical Characteristics:
- Hardness (4-4.5) scratched by knife.
- Sp. Gr. (5.4-5.7) heavy.
- Lustre, sub-adamantine. Translucent.
- Streak, orange yellow. Tenacity, brittle.
- Color, deep red to orange.

Qualitative Tests: Infusible when powdered ore is heated on charcoal. With soda and a little borax yields a white coating. Heated in closed tubes it blackens, turning red again on cooling. Soluble in hydrochloric acid without effervescence.

FRANKLINITE

Composition: A complex iron, manganese, zinc oxide. \((\text{Fe, Mn, Zn})\) \(\text{O} \) (Fe,Mn) \(\hat{\alpha}\) (Zn). When pure it contains 5.54 per cent zinc, 51.8 per cent iron, and 7.5 per cent manganese.
General Description: A black mineral, occurring in compact masses, rounded grains, and octahedred with zincite and willemite.

Physical Characteristics:
- Hardness (6.0-6.5) not scratched by knife.
- Sp. Gr. (5.5-6.2) heavy.
- Lustre, metallic or dull Opaque.
- Streak, brown to black Tenacity, brittle.
- Color, black. Slightly magnetic at times.


Occurrence: Its occurrence is practically confined to Franklin Furnace, N. J.

Other minerals of zinc are wurtzite (ZnS), containing 67 per cent zinc; hydrozincite \(2\text{ZnCO}_3\cdot\text{Zn(OH)}_2\), containing 60 per cent zinc; voltzite \(4\text{ZnS},\text{ZnO}\), a rare oxysulphide of zinc, and goslarite, a hydrated sulphate of zinc.

GEOLOGICAL OCCURRENCE

Geological Horizon: The ores of zinc do not seem to be confined to any particular horizon. Those of the Appalachian belt are Cambro-Ordovician. At Joplin, Mo., and Cumberland, England, they are Carboniferous. In Westphalia they lie in the Devonian limestones, while in the Alpine district the zinc ores are most abundant in the Triassic limestones.

Mode of Occurrence: Zinc ores occur in nature in a great variety of ways:
1. As true metalliferous veins.
2. As cavity fillings not of true fissure vein type.
3. As irregular masses in metamorphic rocks.
4. As irregular masses, or disseminations, formed by replacement or impregnations in limestones and quartzites.
5. As contact metamorphic deposits.
6. In residual clays.

The associated minerals, as stated above, are galena, pyrite, marmatite, and chalcopyrite, with calcite, dolomite, varite, and fluorite as gangue minerals. In the zone of weathering the sulphides are altered to smithsonite, hydrozincite and calamine, and although
these oxidized ores may contain a lower tenor, they may be of greater value than the unoxidized ores, as they often yield more readily to metallurgical treatment than the sulphide ores.

PRODUCTION OF ZINC IN THE UNITED STATES

The zinc ores of the United States are located in three distinct belts as follows:

1. The Appalachian belt—Eastern states. The chief zinc producing district in this belt is the Franklin Furnace region of New Jersey, embracing the great zinc deposits of Sterling Hill and Mine Hill. According to the report of the U. S. Geological Survey, the production of zinc for 1914 was 27,734 tons as against 24,247 tons for 1913. However, the total recoverable zinc in the ore mined was greater than this figure, as much of the ore is converted into zinc oxide for pigment. The other zinc producing states in this belt are Tennessee, Virginia, North Carolina and New York.

2. Central belt—Central states. In this belt the Joplin district, embracing southwestern Missouri, southeastern Kansas, and northeastern Oklahoma, is the most important producer of zinc. In fact it is one of the most important zinc mining districts in the world. The geological section consists of Mississippian cherts and limestones, overlain with Pennsylvanian limestones, shale, sandstones, with occasional beds of coal.

The method of mining in this district is very peculiar. The land holder leases the property for ten years for a royalty of 8 per cent to 15 per cent of the gross value of the output. The lessee prospects by drilling and sinking shafts, by crosscutting, and drifting, and then subleases the property for a royalty of from 15 to 25 per cent of the total gross output of the ores. This method is said to have resulted in the following:

1. The discovery of many new ore bodies.
2. Freedom from serious labor troubles.
3. Increase in the annual output of zinc.

Other important zinc producing areas in this belt are the Upper Mississippi Valley region, embracing adjacent productive areas of Wisconsin, Illinois, and Iowa, the Kentucky-Illinois district and the Arkansas district.

3. Cordilleran Belt—Western states. The chief producer of zinc ores in this belt is the state of Colorado, followed by Montana, Utah, New Mexico, Idaho, Arizona, California and Texas.

The following table gives the production of primary spelter (made
directly from ore) for the period 1909 to 1914 in tons of 2000 pounds:

<table>
<thead>
<tr>
<th>State</th>
<th>1909</th>
<th>1910</th>
<th>1911</th>
<th>1912</th>
<th>1913</th>
<th>1914</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arizona</td>
<td>2,862</td>
<td>2,594</td>
<td>2,336</td>
<td>4,092</td>
<td>4,675</td>
<td>3,905</td>
</tr>
<tr>
<td>Arkansas</td>
<td>135</td>
<td>286</td>
<td>385</td>
<td>604</td>
<td>478</td>
<td>670</td>
</tr>
<tr>
<td>California</td>
<td>1,099</td>
<td>1,672</td>
<td>1,102</td>
<td>159</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colorado</td>
<td>20,121</td>
<td>23,328</td>
<td>42,233</td>
<td>60,841</td>
<td>58,113</td>
<td>41,746</td>
</tr>
<tr>
<td>Idaho</td>
<td>901</td>
<td>3,454</td>
<td>3,180</td>
<td>6,809</td>
<td>10,190</td>
<td>22,720</td>
</tr>
<tr>
<td>Illinois</td>
<td>675</td>
<td>1,551</td>
<td>2,884</td>
<td>3,952</td>
<td>1,346</td>
<td>1,833</td>
</tr>
<tr>
<td>Iowa</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kansas</td>
<td>9,185</td>
<td>10,220</td>
<td>6,843</td>
<td>5,668</td>
<td>9,956</td>
<td>10,634</td>
</tr>
<tr>
<td>Kentucky</td>
<td>22</td>
<td>29</td>
<td>265</td>
<td>394</td>
<td>172</td>
<td>147</td>
</tr>
<tr>
<td>Maine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missouri</td>
<td>140,676</td>
<td>140,652</td>
<td>127,542</td>
<td>149,557</td>
<td>129,018</td>
<td>114,019</td>
</tr>
<tr>
<td>Montana</td>
<td>4,725</td>
<td>12,408</td>
<td>22,115</td>
<td>14,196</td>
<td>35,604</td>
<td>55,986</td>
</tr>
<tr>
<td>Nevada</td>
<td>824</td>
<td>1,516</td>
<td>1,595</td>
<td>6,132</td>
<td>5,828</td>
<td>6,041</td>
</tr>
<tr>
<td>New Jersey</td>
<td>16,035</td>
<td>20,217</td>
<td>15,128</td>
<td>16,941</td>
<td>24,244</td>
<td>24,734</td>
</tr>
<tr>
<td>New Mexico</td>
<td>3,961</td>
<td>4,911</td>
<td>3,778</td>
<td>6,882</td>
<td>3,765</td>
<td>4,345</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>3,008</td>
<td>2,297</td>
<td>2,247</td>
<td>2,041</td>
<td>6,397</td>
<td>9,449</td>
</tr>
<tr>
<td>Tennessee</td>
<td>695</td>
<td>825</td>
<td>1,000</td>
<td>1,935</td>
<td>2,635</td>
<td>6,122</td>
</tr>
<tr>
<td>Texas</td>
<td></td>
<td>245</td>
<td>303</td>
<td>156</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utah</td>
<td>5,960</td>
<td>7,221</td>
<td>7,004</td>
<td>7,756</td>
<td>9,503</td>
<td>6,818</td>
</tr>
<tr>
<td>Virginia</td>
<td>58</td>
<td>1,168</td>
<td>228</td>
<td>62</td>
<td>116</td>
<td>26</td>
</tr>
<tr>
<td>Washington</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wisconsin</td>
<td>20,381</td>
<td>19,752</td>
<td>31,809</td>
<td>34,137</td>
<td>33,743</td>
<td>30,914</td>
</tr>
<tr>
<td>Total</td>
<td>230,225</td>
<td>242,479</td>
<td>271,621</td>
<td>323,907</td>
<td>337,252</td>
<td>343,478</td>
</tr>
</tbody>
</table>

The grand total primary spelter, including the total domestic and total foreign was 353,049 tons for 1914 and 490,000 tons in 1915, showing an increase of almost 50 per cent in the production of spelter in 1915.

**PRODUCTION OF ZINC IN ARIZONA**

The centre of zinc mining in Arizona is the county of Mohave. Two mines, the Golconda and Tennessee, produced in 1915, over 7,000 tons of spelter against about 3,500 tons in 1914. The value of the entire spelter produced in the state was $2,540,000 and more than $2,000,000 of this is credited to Mohave County.

The Mohave County Miner says:

"The Golconda is one of the most ideal zinc mines in the world. Its ore is free from all deleterious bases, that make the western zinc ores hard to handle. It is for this reason that the mine was able to get one of the best contracts ever offered a producing zinc mine in the United States, with a great market all of the time."

In Pima County zinc is found in many different localities, the most important of which are the San Xavier and the Twin Buttes mines. The ore is usually smithsonite, and occurs separately from the other mineral, close to the wall rock.
Zinc is found scattered in many localities in Arizona, but no development has ever been done on them and they are at present of no commercial value.

**BASIS OF BUYING AND SELLING ZINC ORES**

The metallurgy of zinc differs radically from that of any other metal and low grade ores cannot be used directly at the furnace. For this reason the smelter purchases only high grade ores or products obtained by water concentration (including flotation process) or magnetic concentration from low grade ores.

The standard ores are

1. A 60% ore, usually sphalerite, sulphide of zinc.
2. A 30% ore, usually calamine, the silicate of zinc.
3. A 30% ore, usually calamine, the silicate of zinc.

standard figure, the smelters offer a bonus of $1 for every per cent of zinc, in excess of the standard figure, while a deduction of $1 is made for every per cent below the standard figure.

A penalty is imposed on iron at the rate of $1 for each per cent in excess of 1%. Sometimes a penalty is also imposed on lead if it be present in excess of 1%. However, concentrates of sphalerite ore, containing over 6% iron has been bought on the basis of the zinc content, with no special penalty on iron.

**MARKET AND PRICES**

The common term for commercial zinc is primary spelter, i.e. the product derived directly from the ore and not from such sources as drosses, skimmings and old metal. There are four grades of spelter, the names of which, with the permissible proportions of impurities are given below:

<table>
<thead>
<tr>
<th>Proportion of Lead</th>
<th>Proportion of Iron</th>
<th>Proportion of Copper</th>
<th>Proportion of Impurities (Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A or high grade...</td>
<td>0.07</td>
<td>0.03</td>
<td>0.05</td>
</tr>
<tr>
<td>B or intermediate..</td>
<td>.20</td>
<td>.03</td>
<td>.05</td>
</tr>
<tr>
<td>C or brass special.</td>
<td>.75</td>
<td>.04</td>
<td>.75</td>
</tr>
<tr>
<td>D or prime western</td>
<td>1.50</td>
<td>.08</td>
<td>....</td>
</tr>
</tbody>
</table>

The grade produced in largest amount is prime western, a considerable part of which is used for galvanizing iron and steel wire and iron plate.

The main market or basing point for spelter is St. Louis, Mo., but the largest consumption of spelter is at places between St. Louis and
New York, and is sold in New York on a St. Louis basis with the addition of the freight rate on spelter from St. Louis to New York, which is usually 15 cents per 100 pounds.

The price of prime western spelter at St. Louis at the beginning of 1914 was 5.125 cents per pound, and it rose gradually to 5.325 cents early in February, after which a long decline brought the price down to 4.75 cents per pound early in August. After the war broke out, the price of spelter rose rapidly, and by the end of August it was 6c, the highest point of the year. Then, because of the large stock of spelter on hand and because the war orders did not materialize as quickly as expected, it dropped as rapidly and by the middle of October was 4.6 cents, the lowest price of the year. The price rose again and closed the year at 5.5 cents. Though the total spelter produced in the United States in 1915 increased 40 per cent over the year previous, the value of the output, due to the rapid and constant rising price, increased nearly 300 per cent. At present there is still a steady and strong demand for zinc, and because of the scarcity of prompt metal, the prices for spelter are rising every day, and on February 10 it was 19.50 cents at St. Louis and 19.75 in New York.

**METALLURGY OF ZINC**

As stated above, the metallurgy of zinc is very difficult and different from that of other ores. The only process in commercial use, which seems to meet the requirements imposed by the chemistry of zinc, is the retort process. The metal is reduced from the oxide at a higher temperature than is required to volatize the metal, and it is therefore reduced as a vapor, which must be condensed to liquid form. The condensation temperature must be regulated within very narrow limits, or a large part of the zinc vapor will condense as very finely divided zinc mixed with oxide, which fact necessitates the use of small retorts, making the reduction more expensive. On account of these difficulties the zinc smelters can only treat at a profit ores which are concentrated to a comparatively high percentage of zinc.

The concentration of zinc ores is accomplished by
1. Hydro-mechanical processes
2. Electro-mechanical processes
   a. Electromagnetic
   b. Electrostatic
3. Flotation processes. This process besides the fact that it enables us to concentrate the finely disseminated zinc ores, affords a means of separation of the lead from the zinc in the lead-zinc ores.
This is accomplished by selective flotation, where the mixed lead-zinc concentrates are roasted, whereby the lead is converted into sulphates and sinks on floating.

**USES OF ZINC**

The principal uses of zinc are in galvanizing iron wire or sheets and in manufacturing brass. A smaller amount is made into sheet zinc and zinc dust. At the present time large amounts of zinc ore are used in the manufacture of war munitions, especially shrapnel.

The zinc situation is rather a peculiar one, in that the output of zinc is largely controlled by a very few corporations, the greatest part being controlled by the Empire Zinc Co. of New Jersey. Hence, there is no surety, even in spite of the high price of these ores, that they will be purchased. It has been recently reported, however, that the large users of zinc, such as the manufacturers of galvanized iron, etc., will own and operate mines of zinc, and will also be purchasers of zinc ores. If this is so, it will undoubtedly make the mining of zinc a more open and certain venture.