[54] PROCESS AND APPARATUS FOR
CARRYING OUT SAID PROCESS FOR THE
PRECONCENTRATION OF ORES BY
INDUCED MEASURE OF THE
SUPERFICIAL CONTENTS

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Primary Examiner—Allen N. Knowles
Attorney, Agent, or Firm—Sughrue, Rothwell, Mion,
Zinn & Macpeak

[57]   ABSTRACT

The concentration of a desired mineral in pieces of
ore is determined by coating each piece with a fluores-
cent material that selectively adheres only to the ex-
posed surfaces of the desired mineral. The pieces are
then individually illuminated by ultra-violet radiation
to fluoresce the selectively coated material. First
photo-multipliers sense the magnitude of the fluores-
cence and a second photo-multiplier, which detects
the shadow of the ore piece, yields an output propor-
tional, after inversion, to the cross-sectional area of
the ore piece. The magnitude value is then divided by
the area value to indicate the concentration of the de-
sired mineral in the ore piece, which may serve as a
basis for automatically separating the pieces before
further treatment.

4 Claims, 4 Drawing Figures
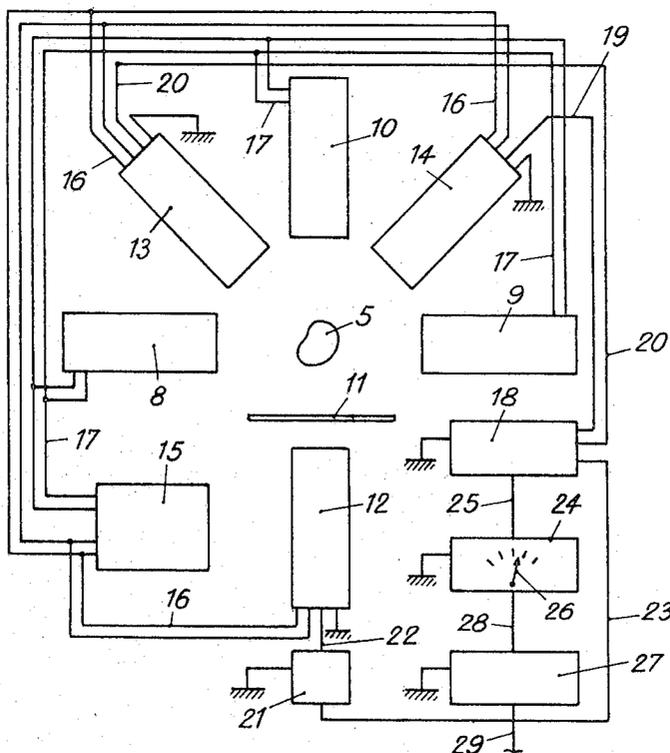
Fig.1

Fig. 2

3,795,310

Fig. 3

Fig. 4

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PROCESS AND APPARATUS FOR CARRYING OUT SAID PROCESS FOR THE PRECONCENTRATION OF ORES BY INDUCED MEASURE OF THE SUPERFICIAL CONTENTS
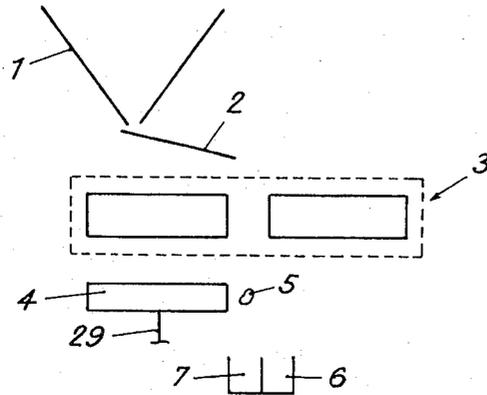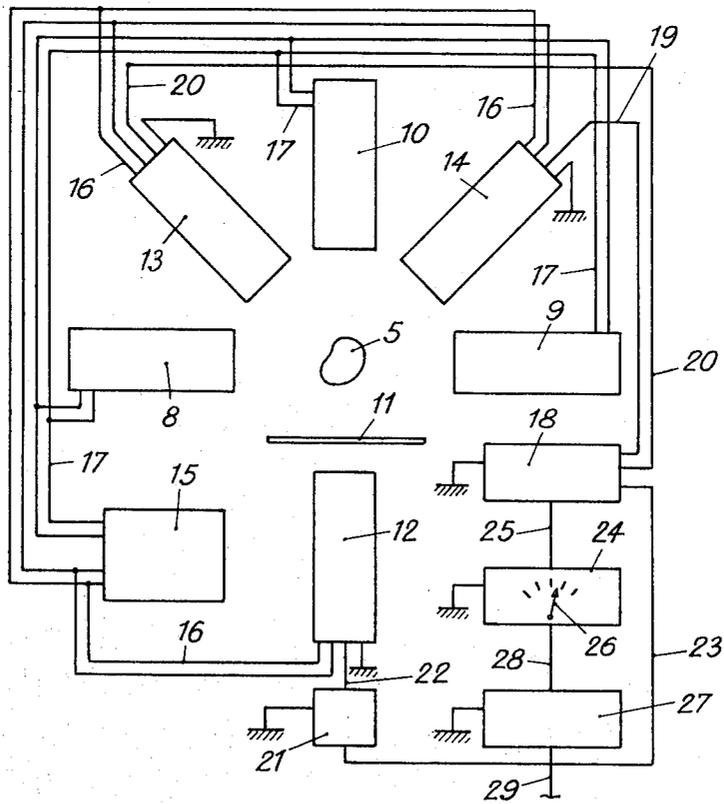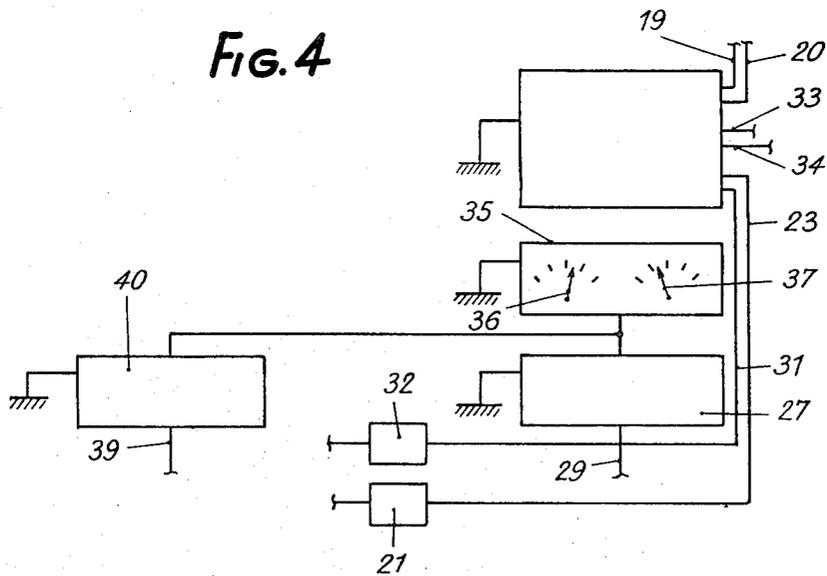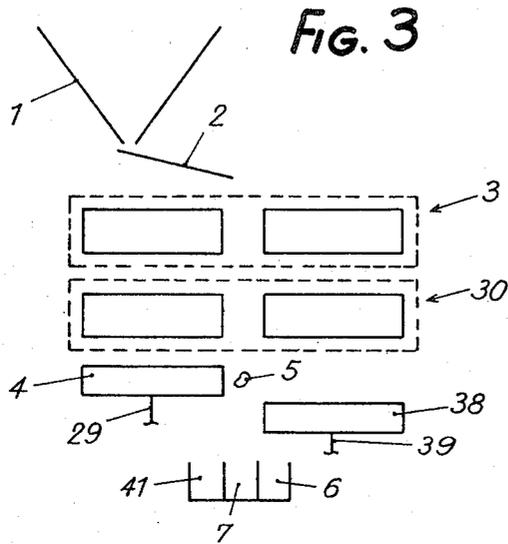
It has long been known to sort fragments of ores by utilising the effects of natural or artificial radiations of the minerals on the surface of the fragments of numerous ores and more recently the use of fluorescent agents has been recommended, with or without collector substances, in order to facilitate the sorting of the fragments as a function of the presence of certain ores.

These methods have the disadvantages of giving only inprecise qualitative results and can be used only when the fragments to be sorted have dimensions varying only within a very narrow limit of 20% at the most. Even apart from the necessary costs for obtaining fragments of dimensions within very narrow limits, it has therefore been impossible to effect an efficient preconcentration of ores containing the desired minerals only in a small or very small content of the order of 0.1% for example, for current metals of relatively low value. In the case of higher contents, the more or less precise concentration could be obtained only at the cost of several screening operations.

In order to evaluate the contents, systems have in fact been proposed using the apparent volume of the fragments, but since no apparatus has yet been designed for determining the superficial contents with precision and comparing them with any predetermined contents, the problem of the precise preconcentration has never been solved, even in the most favourable cases.

The object of the present invention is a process and the apparatus necessary for carrying out this process intended to effect a precise preconcentration of certain minerals existing on the surface of the blocks of ores, the said ores being washed and soaked in a selective collector substance and a fluorescent material for rendering fluorescent any desired portion of the ore during the irradiation of the blocks by an ultra-violet radiation source having a narrow frequency band, the blocks being sorted automatically during the detection of the fluorescent radiation, the said process and the apparatus for carrying out this process being characterised in that the selective action of the collector substance is reinforced either during the washing of the blocks of ore by a wetting and scouring substance selected from an initial group of specific substances, or after the washing, with or without wetting and scouring subtances, by a known substance in the art of flotation, as activating or depressant substance which is chosen from a second specific group, the said process being also characterised by the measurement of fluorescent radiation R emitted by at least one third of the surface of the irradiated fragment, by the measurement of the radiation of a fluorescent screen emitting an amount proportional to $(S-s)$ where S is a constant and has the cross section of the fragment by the calculation of a value which is a function of the content by the display of at least one predetermined content, by the comparison of the value of the calculated amount and of the displayed content and by the selection of the blocks, the calculated content of which is less or greater than the displayed content.

The tests undertaken show that precise preconcentrations can be carried out not only on blocks of ore

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comprising separate minerals, but on blocks comprising unseparated minerals, the predetermined content serving as a point of comparison being capable of being selected either with a view to the selection of a single mineral or to the selection of a group of minerals.

The operation achieved in this manner and terminating in great precision in the selection, has the advantage of being capable of being effected before crushing on ores, whose elements having a value which is to be preconcentrated, are not necessarily liberated. In certain cases the operation may also be effected on any unsorted ore coming from the mine or after simple crushing.

Hence, contrary to known methods, not only can the operation of preconcentration be carried out before any crushing, thus reducing the cost of obtaining the desired mineral or minerals to a very considerable extent, but the scale of granulometry can also be extended as much as possible, taking into account, on the one hand, the output of the selecting apparatus carrying out the described process and, on the other hand, the maximum possible dimensions for the blocks to be treated. Hence, instead of treating only blocks whose dimensions do not vary by more than 20%, blocks may be easily treated whose dimensions vary for example from the single to the triple. By way of example, in an initial apparatus, blocks of 60mm to 130mm may be treated, in a second apparatus, blocks of 20 to 60mm. Moreover, in cases where the fragments have dimensions lower than a given threshold and are no longer economically capable of being preconcentrated due to the poor outputs of the apparatus. It is still possible to reintroduce them into the treatment circuit downstream of the preconcentration of the fragments of larger dimensions.

It will also be noticed, that, as a result of the measurements of a size proportional to $(S-s)$ in which S is a constant and s the vertical section of the block under analysis, obscurites are avoided which result from direct measurement of the content R/s when s tends towards zero, that is to say, in the case of dust.

Another object of the present invention is a process conforming to the stated characteristics and also characterised by the feature that the contents are evaluated by means of two successive analysis stations displaced relatively to each other for analysing the blocks in displaced zones and thus covering almost the whole of the surface of each block.

This characteristic permits a fine analysis not only of blocks of small dimensions, but also of blocks of large dimensions distributed over an extensive granulometric range, this analysis being effected as a function of any value of the predetermined contents, even low values capable of descending approximately to 0.1.

Furthermore, the process which has just been described allows preconcentration of precious metals, the contents of which are of the order of a few grammes per ton, principally when they are associated with sulphur-containing mineral ores: gold associated with mispickel, pyrites etc. In this case, the preconcentration of elements of value is effected by the measurements of the contents of the associated ores.

In order that the invention may readily be carried into practice, two embodiments will now be described in detail, by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a vertical schematic view of the apparatus,

FIG. 2 is a schematic view of the analysing members, accompanied by all the circuits of the apparatus.

FIG. 3 is a schematic view of a variant of the apparatus shown in FIG. 2, and

FIG. 4 shows the control circuits of the calculating and selecting members of the apparatus shown in FIG. 3.

Before any measurement is made of the superficial content of the blocks in a given mineral, preconditioning is effected, consisting of simple washing with water in the presence of a wetting and scouring agent, selected from a group of the following agents:

Soda, lime, sodium carbonate, sulphuric acid, hydrofluoric acid, hydrochloric acid, sulphate and sodium chloride in association with anionic sulphonated or alkylsulphated compounds, pine oil, terpenic, aromatic or hydro-aromatic solvents such as cyclohexanol and tetraline.

This operation has the advantage of powdering the blocks and also of ensuring rapid exposure and intimate contact of the reagents for the preparation of the surfaces used in the course of the second conditioning. This is the treatment of sulphur-containing mineral ores of Cu, Pb, Zn, Ag, Au, Sb, Mo for separating sulphides from the gangue by 500 to 25,000g of one of the following agents:
soda, lime, sodium carbonate or sulphur acid, which is mixed with 1–2 m³ of water for 1 ton of ore.

The feldspaths conditioned for their separation from the quartz are treated either with sulphuric acid at the rate of 500 to 1,000g per ton of ore, the acid being dissolved in 1 – 2 m³ of water, or by hydrofluoric acid at the rate of 400 – 600g per ton of ore.

For its separation from the quartz of the iron oxide the conditioned barite is treated with sodium carbonate at the rate of 550 to 900g dissolved in 1 – 2 m³ of water per ton of ore.

The conditioned quartz is treated with 200 – 500g of hydrofluoric acid per ton of ore for separation from calcite.

After this initial conditioning, the second conditioning is effected and, for this purpose, the ore originally washed with or without a wetting and scouring agent is mixed in any suitable apparatus, a trommel for example.

In case of sulphur-containing ores of Cu, Pb, Zn, Ag, Au, Sb, Mo, a solution comprising 50 – 500 grams of xanthate or dithiophosphoric acid for 1 ton of ore is selected as collector and copper sulphate is used at the rate of 250 – 500g per ton of ore as activator.

The fluorescent reagent used is then preferably anthracene dissolved in benzene and at the rate of 10 – 60g per ton of ore.

For oxidised ores of Cu, Pb, Zn, a long-chain xanthate such as hexlyxanthate or again mercaptobenzothiazol at the rate of 300 – 700g is selected as collector and, as activating agent, sodium sulphide at the rate of 1,000 – 4,000g per ton of ore.

For Feldspaths, a collector such as amineacetate at the rate of 200 – 600g per ton of ore will be sufficient.

For the separation of calcite from the quartz, oleic acid is used as collector, at the rate of 200 – 1,000g for 1 ton of ore and this treatment is completed by a depressant:

sodium silicate at the rate of 100 – 250g per ton of ore, without it being necessary to add a wetting and scouring agent to the initial washing.

In the case of barite, a sodium oleate or a sodium sulphonate or a tall-oil is used as collector, at the rate of 200 – 500g per ton of ore, and the treatment is completed by the action of a depressant: starch at the rate of 50 – 200g per ton of ore, starch being a depressant of iron oxide.

The separation of quartz fluorine is effected by selecting as collector sodium oleate at the rate of 100 – 300g per ton of ore — the first conditioning may be effected without the use of a scouring agent.

The separation of potash from its gangue or veinstone and of NaCl, is effected by selecting an amino acetate or an amino hydrochloride at the rate of 200 – 500 per ton of ore and by completing this treatment with a depressant: starch, at the rate of 50 – 100g per ton of ore, it being possible to effect the first conditioning without the use of a scouring agent.

In the separation of quartz from calcite, an acetate or an amino-hydrochloride is used as collector at the rate of 200 – 500g per ton of ore, — the first conditioning is effected by using hydrofluoric acid.

In all the cases which have thus been mentioned, the fluorescent agent is preferably anthracene dissolved in benzene at the rate of 10 – 60g per ton of ore.

However, anthracene may also be replaced by the following agents: naphthacene, pentacene, chrysene, dibenzanthracene, fluoresceine, eosine, erythresine, rhodamine, azines such as primuline for example, esculine, sulphate of quinine.

In general, experiece has shown that the preparation of the surfaces depends on the one hand, on the physico-chemical techniques of the flotation reagents and, on the other hand, on the solubilisation of these reagents in a solvent capable of emitting fluorescent light under the action of ultra-violet irradiation. Hence, the reagents employed are of the same type as those required in the flotation of fine mineral particles and comprise the conventional anionic or cationic collectors, activating agents, depressants, regulators. Since these reagents are not generally fluorescent per se, they are used in solution in a liquid fluorescent under ultra-violet light, such an anthracene dissolved in the aforesaid benzene.

The method may therefore be applied to all minerals in blocks wherein the useful products are native metals or metalloids copper, silver, gold, sulphur, graphite or metallic sulphides, of iron, zinc, lead, copper, silver or non-sulphur containing ores, cerusite, magnetite, ilmenite, tungsten, fluorine, barite etc.

After proceeding under the stated conditions: washing with or without a wetting or scouring agent, then treatment with the reagents of the art of flotation, combined with solubilisation of these reagents with a solvent emitting a fluorescent light under the action of ultra-violet irradiation, the blocks of ore are emptied into the hopper 1, FIG. 1, from where they flow one by one through any known distributing device 2 to drop down a free chute to an analysis section 3, shown in FIG. 2, which controls a mechanical selecting device 4. When the device 4 is controlled, the block 5, which has just been analysed, is deflected to the right to drops into the passage 6; in the contrary case, the block 5 drop into the passage 7.

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The analysing device 3, shown in FIG. 2, comprises three ultra-violet radiation sources 8, 9, 10, the source 10 projecting onto the red fluorescent screen 11 a beam partially intercepted by the block 5 analysed in the course of its fall. The beam of red light coming from the screen 11 is detected by the photomultiplier 12, whilst the induced light produced by the ultraviolet radiation on the surface of the block 5 is detected by the photo-multipliers 13 and 14. The source 8 – 10 and the photo-multipliers 12 and 14 are supplied with suitable filters in order to avoid any alteration in the measurements of the radiation. A current source 15 feeds the photo-multipliers 12 – 14 through the wires 16 and the sources 8 – 10 through the wires 17.

A calculator 18 receives the measurements of induced radiation of the block 5 through the wires 19 and 20. The radiation received from the screen 11 by the photo-multiplier 12 is proportional to S-s in which S is the surface of the fluorescent screen 11 emitting under the action of the radiation received in the absence of the block and in which s is the vertical section of the analysed block. The measurement of the radiation of the fluorescent screen is transformed by the inverter 21 connected to the photo-multiplier 12 by the wire 22 to supply the calculator 18, through the wire 23, with a value proportional to s-S. Hence the calculator 18 receives a current (or, if desired, a voltage, according to the technology employed) proportional to the induced radiation of the surface of the block 5 through the wires 19 and 20 and a current or voltage, as a function of the cross-section of the block 5, through the wire 23. The calculator thus makes it possible to transmit to the comparator at 24 through the wire 25, an amount which is a function of the superficial content of the block 5, which content is practically that of the mass content.

The comparator 24 compares the value of this amount with the predetermined and adjustable value displayed by means of the button 26. The result of this comparison is transmitted to the control member 27 of the selection mechanism 4 through the wire 28. A wire 29 connects the control member 27 to the selection mechanism 4 shown in FIG. 1.

In the embodiment shown, the source 10 is disposed on an axis perpendicular to the common axis of the sources 8 and 9. The axis of the photo-multiplier 12 is in the extension of the axis of the source 10.

When the blocks have very heterogeneous surfaces, the analysis station is doubled and the axes of the devices of the second station are displaced through a certain angle relatively to the axes of the first station. The induced radiation is therefore produced in a part of the block which had not yet been subjected to the radiation during the exposure to the first station. In the embodiment shown in FIG. 3, the second station 30 is displaced through an angle of 180°, so that the differences of the induced radiation may be compared for the same section of the analysed block.

The calculator 31, FIG. 4, thus receives both the amounts coming from the station 3 through the wires 19, 20 and 23 and from the station 30 through the wire 31 connected to the inverter 32, similar to the inverter 21 of the first station, and through the wires 33 and 34 connected to the photo-multipliers corresponding to the photo-multipliers 13 and 14 of the first station. Although only one result is transmitted to the comparator 35, said comparator may comprise two buttons 36

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and 37 adjustable in position for displaying two predetermined values of the contents. The apparatus is therefore supplied with a second selecting device 38, FIG. 3, connected by the wire 39 to a second control member 40, FIG. 4. The devices 4 and 38, FIG. 3, are mounted in separate directions so as to deflect the blocks 5 either towards the passage 6, or towards the passage 41, the blocks dropping into the passage 7 in the absence of a control of the devices 4 and 38. It is therefore only necessary to display two values by means of the buttons 36 and 37 so that the blocks, the contents of which are less than the minimum content drop into the passage 6, and the blocks having contents between these two values drop into 7 and the blocks having a content greater than the highest, drop into 41.

Again, as a variant, the three sources could be arranged at an angle of 120° relatively to the axes and the second station arranged by displacing the axes of these sources relatively to those of the first station.

In this manner, any dead angle is avoided which might involve falsification of the measurements.

The apparatus therefore makes it possible to sort blocks of ores which may be previously separated with the following granulometries, for example: 80 – 120 mm, 50 – 80 mm 20 – 50 mm. It is obvious that it would be possible, if desired, to treat blocks of less than 20 mm, which case, although special, is not excluded.

The described process makes it possible to preconcentrate a large number of ores. For example, preconcentration of a pyrite and chalcopyrite ore has been obtained by proceeding in the following manner:

The ore is subjected to an initial conditioning in a trommel for 5 minutes in the presence of water and 1kg of sodium carbonate per ton of ore, this mixture being followed by rinsing in a jet of water at the outlet of the trommel.

The second conditioning is effected by using 300g of potassium hexylxanthate per ton of ore dissolved in a fluorescent mixture containing 4g of anthracene in solution in 70ml of benzene.

The passage through the automatic sorting apparatus is effected at three successive levels or thresholds of contents and makes it possible to collect the products appearing in the following Table:

Products	Weight %	Cu %	Recovery % of Cu
Concentrate 1	33	3.65	62.2
Concentrate 2	13	2.35	15.9
Concentrate 3	12	1.25	7.8
Reject	42	0.65	14.1
Unsorted material	100	1.90	100.0

The reject content rises to 0.65% of Cu, and this value is bound to the minerological constitution of the treated ore, with diffused mineralisation.

A test on sulphur-containing lead and zinc ore in fragments of 30 – 80mm was conducted under the same conditions as before and subjected to automatic sorting. The ore is thus separated into a preconcentrate of galena and a reject lower than 0.1% of Pb.

This reject, having a rich content of zinc sulphide, is subjected in turn to a further conditioning for 5 minutes in the presence of 100g copper sulphate per ton of ore, then, for a further 5 minutes, in the presence of 1,000g hexylxanthate per ton of ore and 250g per ton of anthracene in a benzene solution. After rinsing in water and automatic sorting, it is possible to recover from the residual blocks having only a very low content

of lead, those whose content of zinc is greater than 0.1%.

The results of this differential sorting operation appear in the following Table:

Product	Weight%	Pb%	Zn %	Recovery % Pb	Recovery % Zn
Concentrated Pb	34.7	2.80	15.35	93.6	72.8
Concentrated Zn	34.6	0.15	5.20	5.0	24.7
Reject	30.7	0.05	0.60	1.4	2.5
Unsorted material	100.0	1.05	7.30	100.0	100.0

It will be noted that the quantities of reagents employed may very within appreciable proportions of the order of −50 to +100%. Thus, the duration of soaking may vary from 2 − 10 minutes, the quantity of coppper sulphate from 50 − 200g, that of hexlyxanthate from 500 − 1,800g and anthracene from 150 − 400g.

What we claim is:

1. An apparatus for effecting the precise preconcentration of specific minerals disposed on the surface of blocks of ore, comprising: at least two sources of radiation simultaneously irradiating a block dropping into a field of radiation common to the two sources, at least two photo-multipliers for transforming the radiations received into a first signal whose amplitude is proportional to the superficial content of each block of a given mineral, means for establishing a second signal whose amplitude is proportional to a pre-determined content of said given mineral, means for comparing the amplitudes of the first and second signals, and a mechanical selector actuated by the comparator each time the amplitude of the first signal is greater than the amplitude of the second signal.

2. An apparatus as claimed in claim 1, wherein the two sources are disposed on the same axis on opposite sides of the trajectory of the blocks, and further comprising a third source perpendicular to the axis of the two opposed sources, a red fluorescent screen being disposed perpendicularly to the axis of the third source and on the side opposed to that relatively to the trajectory of the blocks, two initial photomultipliers receiving the induced radiation of the blocks and a third photomultiplier receiving the radiation of the red fluorescent screen, an inverter receiving the result of the measurement of the third photo-multiplier, and a calculator, connected to the inverter and to the two initial photo-multpliers, to provide a value which is a function of the superficial content of each block.

3. Apparatus as claimed in claim 2, comprising two stations for determining the superficial content of each block, the axes of the sources and of the photo-multipliers of each station being displaced, through a certain angle relatively to the axes of the other station in order to produce a reduced radiation on the portion of the block not yet energised by the radiation of the sources of the other station.

4. An apparatus as claimed in claim 1 comprising two means of displaying pre-determined contents, two comparators to determine if the superficial content of the analysed block is less than the lowest quantity displayed, greater than the maximum content or between them, two selecting mechanisms and three selection passages in order to deflect the blocks of low, intermediate or high contents into the passages assigned to them.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. __3,795,310__   Dated __March 5, 1974__

Inventor(s) __Pierre Charles BUCHOT et al__

    It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

IN THE SPECIFICATION:

Column 1, before line 6, insert

--The present invention, due to P. Buchot, R. Cohen-Allaro and J. C. Robert in the course of work entrusted to them by the applicant Company, concerns a process and the apparatus employed for carrying out said process for the preconcentration of ores by automatic sorting of their different fragements varying in the concentration of one or more specific elements.--

Column 4, lines 16-17, after "200-500", insert "g".

Column 4, line 34, "experiece" should be "experience".

Column 4, line 66, "drops" should be "drop".

Column 4, line 67, "drop" should be "drops".

Column 7, line 14, "very" should be "vary".

Column 8, line 20, after "displaced", delete ", ".

Column 8, line 25, after "claim 1", insert --, --.

Signed and sealed this 26th day of November 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents