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Books and Pamphlets:

Canadian mining manual 1962. Gardenvale, Que.: National Business Publications Ltd., 1962. 271 p., illus., diagrs., flowsheets, tabs. (Presented by the publisher.)

THE CHAMBER OF MINES OF RHODESIA (INCORPORATED). *Twenty-third annual report for the year 1961*. Salisbury: The Chamber, 1962. 59 p., tabs. (Presented by the Chamber.)

NORTHERN RHODESIA CHAMBER OF MINES. *Year book 1961*. Kitwe: The Chamber, 1962. 76 p., illus., tabs. (Presented by the Chamber.)

**Oil & petroleum year book 1962 incorporating the oil and petroleum manual*. London: Walter E. Skinner, 1962. 783 p., illus. 40s.

ROGERS, R. R., ed. *Iron ore reduction*. Proceedings of a symposium of the Electrothermics and Metallurgy Division of the Electrochemical Society held in Chicago, 3–5 May, 1960. Oxford, New York, etc.: Pergamon Press, 1962. 359 p., illus., diagrs., tabs., biblios. 80s.

UNIVERSITY OF THE WITWATERSRAND, ECONOMIC GEOLOGY RESEARCH UNIT. *Third annual report: 1961*. D.A. Pretorius. Johannesburg: The Unit, 1962. 17 p.

Government Publications:

AUSTRALIA, COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION. *Fourteenth annual report 1961–62*. Melbourne: The Organization, 1962. 153 p., illus., tabs., biblio.

CALIFORNIA, DIVISION OF MINES. *Legal guide for California prospectors and miners (revised ed. 1962)*. Richard M. Stewart. San Francisco: The Division, 1962. 28 p., maps. $1.

CANADA, DEPARTMENT OF MINES AND TECHNICAL SURVEYS. *Annual report, calendar year 1960*. Ottawa: Queen's Printer, 1961. 61 p., illus., diagrs. $1.

——— MINERAL RESOURCES DIVISION. *The Canadian mineral industry, 1961* (Preliminary). *Cement; Cobalt; Niobium (columbium) and tantalum; Petroleum; Selenium and tellurium; Titanium*. Ottawa: The Department, 1962. Variously paged, diagrs., tabs.

GREAT BRITAIN. NATIONAL COAL BOARD, PRODUCTION DEPARTMENT. *Shotfiring in coal mines*. (3rd rev. ed. 1962.) London: The Department, 1962. 93 p., diagrs., tabs. (Presented by the Department.)

IRELAND, REPUBLIC OF, MINISTRY FOR INDUSTRY AND COMMERCE. *Minerals Development Act, 1940. Report by the Minister . . . for the six months ended 30th June, 1962*. 23 p., tabs. *P.R. 6745*.

Petroleum and Other Minerals Development Act, 1960. Report by the Minister . . . for the six months ended 30th June, 1962. 2 p. *P.R. 6746*.

Dublin: The Ministry, 1962.

NEW ZEALAND, MINES DEPARTMENT. *Mines statement incorporating the report on the working of the state coal mines for the year ended 31 December, 1961*. Wellington: R. E. Owen, Govt. Printer, 1962. 103 p., tabs.

NIGERIA, GEOLOGICAL SURVEY. *Annual report . . . 1960 61*. Lagos: Federal Ministry of Information Printing Division, 1962. 18 p., map, tabs. 9d.

SOMALI REPUBLIC, MINISTRY OF COMMERCE AND INDUSTRY, GEOLOGICAL SURVEY DEPARTMENT. *Annual report . . . for period April 1960 March 1961*. Hargeisa: The Department, 1962. 17 p., tabs. 2s. 6d.

UNITED STATES, BUREAU OF MINES. *Minerals yearbook 1961*. Preprints. *Arsenic; Beryllium; Bismuth; Bromine; Cadmium; Calcium and calcium compounds; Diatomite; Graphite; Helium; Kyanite and related minerals; Lithium; Magnesium; Minor nonmetals; Molybdenum; Potash; Quartz crystal (electronic grade); Strontium; Vanadium; Zirconium and hafnium; Review of metallurgical technology; Review of mining technology*. Washington: Govt. Printing Office, 1962. Variously paged, diagrs., tabs., biblios.

Investigation into Jig Performance*

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SYNOPSIS

Some tests with a small laboratory Hartz jig are described.

The main object of the tests was to investigate quantitatively the effect of variations in length and speed of stroke, and in jig bed current, on the proportion of the feed reporting at the jig spigot, and on the percentage recovery of cassiterite. A specimen of natural stanniferous alluvium from the Batang Berjuntai tinfield in Malaya was used for the tests.

The effects of varying the percentage of cassiterite in the feed, and of removing the coarsest particles in the feed, were also briefly investigated.

THE TESTS CARRIED OUT FORM PART of a programme of work undertaken to investigate what steps might be taken to improve the performance of the primary jigs on the dredges under the management of Anglo-Oriental (Malaya), Ltd. Standard reference works on the subject deal almost exclusively with the recovery of galena and sphalerite and give much detailed information relating to the adjustment of and results obtained by jigs on many properties, but rather little about recovery of placer cassiterite.

The writer is aware of the dangers of generalizing on jig performance when so many variables are involved and so much depends on the nature of the material treated, especially in relation to the slime content. Nevertheless, bearing these limitations in mind, it was considered worth while to investigate the general pattern of jig performance with the fairly slime-free tin-bearing alluvium which is typical of some of Malaya's alluvial tin deposits.

EQUIPMENT

The jig used for the tests was a single-hutch Hartz-type machine with a plunger and jig bed each 124 sq.in in area ($11\frac{1}{8}$ in. square). The jig was driven by a fixed-speed electric motor through a pulley and belt drive and a fixed-ratio gear box. By using combinations of pulleys with a variety of diameters the speed of the stroke could be varied in a number of steps from a minimum of 50 to a maximum of 257 strokes/min. The acceleration pattern of the plunger movement was simple harmonic. Adjustment on the eccentric permitted the length of stroke to be varied from a minimum of $\frac{1}{20}$ in. to a maximum of $1\frac{1}{2}$ in.

The hutch was in the form of an inverted pyramid with steeply sloping sides terminating in the spigot pipe to minimize retention of spigot product in the hutch and to simplify washing down the inside of the hutch. Hutch

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make-up water was supplied as required to the plunger compartment above the plunger from a tank maintained at constant head.

TEST PROCEDURE

The tests were run on a batch basis, using 1 cu.ft of material. The normal experimental procedure of altering one variable only in each succeeding test was followed.

Before the tests were begun some alluvial material of the same type as that used in the tests was run over the jig to allow the bed to reach a state of equilibrium. A certain amount of sand and cassiterite of mesh finer than the jig screen apparently 'floats' in the jig bed indefinitely after the feed has been discontinued. The equilibrium condition probably varied somewhat from one test to another, but this does not appear to have affected the general consistency of the results, although it may have contributed to some of the anomalies and to the scatter of the points on the graphical representation of the results.

The length and speed of stroke and rate of flow of hutch water were set to the required values and then 1 cu.ft of material, well-compacted, was fed into the jig feed box by hand, as steadily as possible, in the pre-arranged time of about 6 min, together with a measured amount of feed water from a perforated pipe in the feed box. The jig was run until no more tailing was discharged.

The volumes of spigot product and tailing were then measured, from which the proportion by volume of feed reporting in the spigot was calculated. Both products were then separately washed in a 'dulang', after screening out +10-mesh material, which contained no free cassiterite, to produce a rough concentrate. The concentrate was cleaned to about 76 per cent Sn by hand dressing, this figure being checked on the zinc block.

From tests involving the washing of made-up samples by dulang it has been established that if a dulang is used by a skilful operator washing only small quantities of material (about 200 c.c.) at a time, losses in the range −14 +200 mesh will be less than 10 per cent of the free cassiterite. Accordingly this system of determining the amount of cassiterite was used and the work was carried out by the same personnel throughout the test series. This procedure was regarded as acceptable, since the results were mainly required to be only comparative in nature.

All the various products were then remixed, the volume check was measured and the next test on the schedule run.

Definitions

The displacement is in cu.in per sq.ft of jig bed.

Since the jig bed and plunger areas are both equal to 124 sq.in, the volume of water displaced by one down stroke of the plunger $= l \times 124$ cu.in, where l is the length of stroke in inches. The plunger was made of wood edged with rubber insertion and was a good fit in the plunger compartment; slip has therefore been neglected.

The volume of water displaced per sq.ft of jig bed per stroke $=$ length of stroke $\times$ 144 cu.in.

The speed is in strokes per min. The intensity of stroke is defined as the cu.ft displaced in one direction per sq.ft of jig bed per min.

The displacement in the jig used for the experiments, expressed in cu.ft per sq.ft of jig bed, is $l/12$, where l is the length of stroke in inches. If the speed is S strokes per min, the intensity of stroke $= \dfrac{l \times S}{12}$ cu.ft/sq.ft/min.

The jig bed current, as determined by the difference between the spigot flow and hutch water, is recorded in gal/sq.ft of jig bed per min. The net current may be falling or rising, or zero.

As a matter of convenience the pulp density of the feed is expressed as the percentage by volume of the sand to the total volume of sand plus feed water used during the test, instead of the usual ratio of solids to liquids by weight.

The recovery is taken to be the percentage by weight of the cassiterite washed from the spigot product to the total weight of cassiterite washed from the spigot product and tailing.

Variable factors kept constant

Throughout the tests the following factors were maintained as close as possible to the values given below:

Ragging, hematite; size range $-\frac{3}{4}$-in $+\frac{1}{4}$-in ring, depth $1\frac{1}{2}$ in.
Pulp density about 14 per cent
Feed rate about 0·4 cu.yd/sq.ft/h
Jig bed slope 1 in 24
Jig screen $\frac{1}{2}$-in by $\frac{1}{8}$-in holes in mild steel plate
Distance between hole centres 1 in. by $\frac{1}{4}$ in. staggered
Spigot hole diameter 0·35 in.
Maximum size of feed particles $\frac{1}{2}$-in ring (except where stated).

The jigging was done through the screen only, as the material is known to contain no free cassiterite coarser than $\frac{1}{8}$ in. in size.

RESULTS

The tests consisted mainly of an investigation into the dependence of recovery of cassiterite by the jig and the dependence of the proportion by volume of feed reporting at the jig spigot on:

series (*a*)—displacement and speed of stroke
series (*b*)—jig bed current.

A few tests were carried out to examine the dependence of the factors mentioned on variation of the value of the feed and the maximum grain size of the feed.

The results of the tests in series (*a*) are shown graphically in Fig. 1. The value of the feed, after screening to $-\frac{1}{2}$ in., was about $1\frac{1}{2}$ lb of cassiterite per cu.yd. Each test is represented by a point the position of which corresponds to the displacement and speed of stroke in use during that test. The figures to the left and right of the points are the percentage by volume of feed

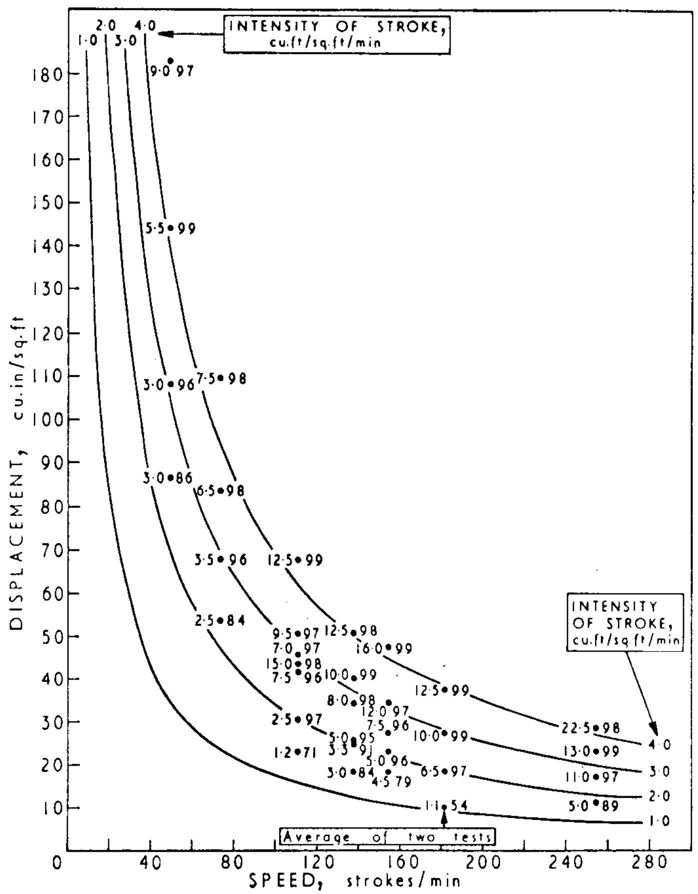

Fig. 1.—Dependence of recovery and spigot product proportion on displacement and speed of stroke. Jig bed current, 0·5–0·8 gal/sq.ft/min (falling).

reporting at the spigot and the percentage recovery of cassiterite in the feed, respectively. The lines of equal intensity of stroke are plotted in Fig. 1.

In general, as the displacement is increased at a given speed of stroke, both the proportion of feed reporting at the spigot and the recovery increase. Similarly at a given length of stroke both these quantities increase as the speed is increased. There are some exceptions to the general trend, particularly at a speed of 111 strokes/min. The reasons for these anomalies are not known and they may have no significance beyond indicating imperfection of experimental technique. On the other hand they may possibly indicate a state of resonance.[1]

The main conclusion to be derived from Fig. 1 is that the recovery is essentially constant for a given intensity of stroke.[2] This is clearly seen if

[1]etc. See list of references at the end of the paper.

the line representing an intensity of 3 cu.ft/sq.ft/min is followed from a jig speed at 50 strokes/min to one of 257 strokes/min.

In some tests carried out at a given speed at the longest strokes, there is a slight, but probably significant, falling off in recovery, which may be due to overloosening of the bed and turbulence.[3]

At speeds below 100 strokes/min the recovery falls off fairly rapidly at intensities of stroke of less than 3 cu.ft/sq.ft/min. At speeds above 100 strokes/min the recovery does not start to fall sharply until the intensity of stroke is less than 2 cu.ft/sq.ft/min. There is presumably no actual discontinuity, this being an illusion resulting from the absence of tests in the range 75 to 110 strokes/min.

The relationship between the proportion of feed reporting at the spigot and intensity of stroke is more complex. For a given intensity of stroke the proportion of feed reporting at the spigot drops off fairly steadily from high to low speeds. For example, on the line for an intensity of 3 cu.ft/sq.ft/min the proportion of feed reporting at the spigot drops from about 12 per cent at 257 strokes/min to 3 per cent at 50 strokes/min for very little reduction in recovery. It therefore appears that, at least with this particular material, low speeds give a higher ratio of enrichment than high speeds for approximately the same recovery. In this respect slow speeds may be said to be more efficient than high speeds.

In Fig. 2 the recovery of cassiterite has been plotted against the corresponding proportion of feed reporting at the spigot. The recovery rises

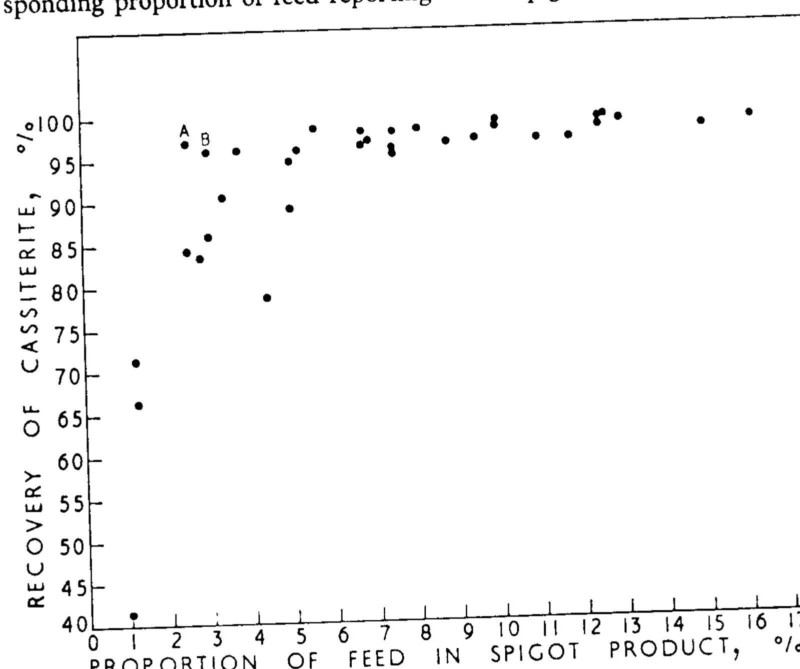

Fig. 2.—Relation between recovery and spigot product proportion at various displacements and speeds. Bed current, 0·5–0·8 gal/sq.ft/min (falling).

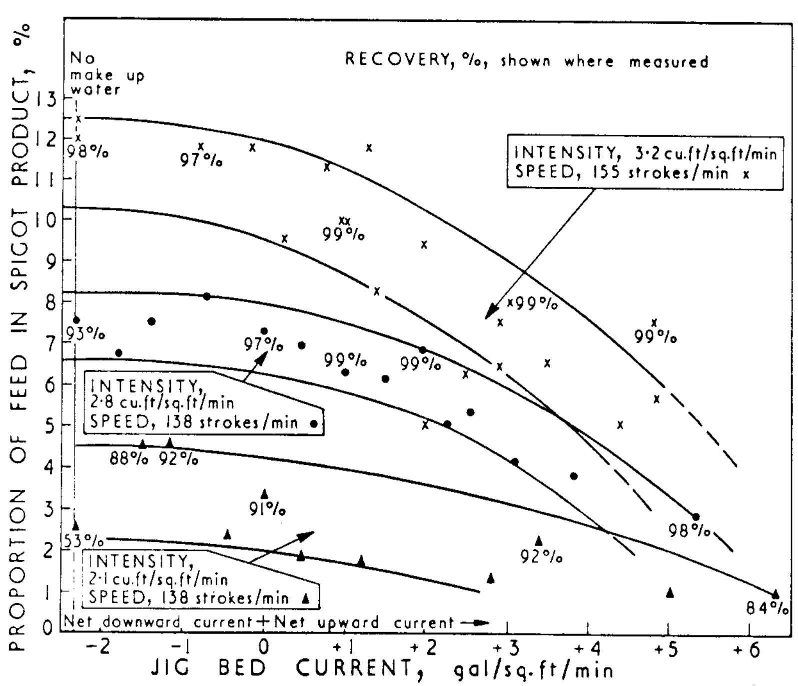

Fig. 3.—Dependence of spigot product proportion on jig bed current.

very sharply at first, but flattens off at a point where about 7 per cent of the feed reports at the spigot. Between percentages of 2½ and 6 per cent the points on Fig. 2 show a good deal of scatter, although it should be noted that the two points marked A and B correspond to tests carried out at 50 strokes/min, illustrating the higher efficiency at slower speeds already mentioned. When the proportion of feed reporting at the spigot was above 7 per cent no test in series (*a*) gave a recovery of less than 95 per cent.

The results of series (*b*), at three different intensities of stroke, are shown in Fig. 3. The points show considerable scatter, especially at the highest intensity of stroke, but nevertheless fall into three distinct groups, which merge together for large net upward values of jig bed current. As the flow of make-up water is increased the proportion of feed reporting at the spigot decreases slowly at first, then more rapidly.

The effect on recovery is more complex. At the lowest intensity of 2·1 cu.ft/sq.ft/min, starting with very little or no make-up water, there is a sudden increase in recovery between no hutch water and a net downward bed current of 1·5 gal/sq.ft/min. With further increase in hutch water the recovery remains fairly steady until the net upward jig bed current reaches a value in excess of 5 gal/sq.ft/min when there is some reduction in recovery. With no make-up water the jig bed was very sluggish, the short stroke failing to dilate the bed sufficiently in the face of the net downward current to allow a good recovery. At an intensity of 2·8 cu.ft/sq.ft/min these effects are still present, although to a much lesser degree, while at the highest intensity used the jig bed current has little effect on recovery.

The composite screen analysis of the tailing, spigot product and the concentrates washed from these two products in twelve tests are given in Table I. The recovery was somewhat better in the coarse and medium mesh fractions than in fractions below 100 mesh B.S.S. on the basis used for measuring in these tests. In general the sets of figures for the two concentrates follow each other fairly closely, indicating the absence of a decrease in recovery in the medium ranges.[4] The small proportion of cassiterite finer than 200 mesh is not an illusion caused by excessive losses in washing. Tests on this alluvium, in which the slime was recovered by pressure filtering, show that there is in fact little free cassiterite in the 200–300-mesh fractions, although probably most of the cassiterite lost in the dulang tailing consisted of fine-grained mineral, which if it had been accounted for might have modified the distribution slightly.

A short series of tests was carried out using feeds of varying value. The variation of value was achieved by taking cassiterite from or adding it to the standard material in the correct proportion for each mesh fraction. At the richest value the proportion of cassiterite in the feed was only of the order of ½ per cent, so that the overall screen analysis of the feed was virtually unchanged. In five tests the value of the feed was varied from ½ lb/cu.yd to 12 lb/cu.yd. The recovery did not vary by more than ½ per cent above or below 94 per cent and thus within this range of values the recovery may be said to be independent of the value of the feed.

In all the tests so far described the +½-in ring fraction had been

TABLE I

Mesh B.S.S.	Sand		Concentrate	
	Tailing, %	Spigot product, %	Tailing, %	Spigot product, %
+10	41·9	0·1	Nil	Nil
10/25	27·4	8·8	0·3	0·5
25/52	15·2	28·3	3·4	4·8
52/72	7·5	29·9	37·1	48·4
72/100	4·5	20·7	33·4	34·4
100/120	1·3	5·1	13·6	8·5
120/150	1·2	4·5	5·5	1·9
150/170	0·3	1·0	2·4	0·6
170/200	0·3	0·7	2·3	0·5
200/240	0·2	0·5	1·1	0·2
240/300	0·1	0·2	0·5	0·1
−300	0·1	0·2	0·4	0·1
	100·0	100·0	100·0	100·0

screened out of the material used, so as to make it similar to the type of material treated by the primary jigs on operating dredges.

Finally a test was carried out on feed from which the +10-mesh material had been screened, for comparison with a test on standard material, but with all other conditions the same. The results are given in Table II.

TABLE II

Feed	$-\frac{1}{2}$-in	-10-mesh
Proportion of feed reporting at spigot, % . . .	3·3	5·9
Recovery % . . .	91	96

This test is of some interest in regard to the consideration of secondary screening on bucket dredges. The existing jig capacity of a dredge treating this particular material might be increased if it were economically practicable to screen out the +10-mesh material.

CONCLUSION

A pattern of jig behaviour has been established, in terms of variation of speed and length of stroke and jig bed current for one particular type of feed and under the other conditions listed.

As the material employed in the tests was fairly typical of the alluvium treated by many tin dredges it is hoped that the results will have some applicability to the adjustment of dredge treatment plants. A sampling programme of spigot products and discards from the primary jigs of several dredges, run concurrently with the above work, indicates that this is the case.

It is proposed to increase both the scope and scale of this work in future tests, employing a full-size jig, and to investigate some of the other important variables, particularly those relating to rate and type of feed.

Acknowledgement.—This report is published with the permission of Anglo-Oriental (Malaya), Ltd. The work was carried out with the assistance of Mr. J. C. Liu at the company's ore dressing laboratory near Kuala Lumpur.

REFERENCES

1. Lill, G. D., and Smith, H. G. A study of the motion of particles in a jig bed. *International Mineral Processing Congress, 1960* (London: Institution of Mining and Metallurgy, 1960), 515–35.

2. Taggart, A. F. *Handbook of mineral dressing* (N.Y.: Wiley, 1945), Section 11, 04–55.

3. Kirchberg, H., and Hentzschel, W. A study of the behaviour of particles in jigging. *Progress in mineral dressing* (Transactions of the International Mineral Dressing Congress, Stockholm, 1957). (Stockholm: Almqvist and Wiksell, 1958), 193–215.

4. Chaston, I. R. M. Developments in the treatment of Malayan tin ores. *International Mineral Processing Congress, 1960* (London: Institution of Mining and Metallurgy, 1960), 593–609.

Elemental Constitution of the Black Star Orebodies, Mount Isa, Queensland, and its Interpretation*

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553.1:546:553.661.2(943.4)
553.43/4(943.4):553.068

SYNOPSIS

The abundances and abundance relationships of the major constituents of the Mount Isa lead-zinc and copper ores are examined and discussed, using as principal examples the Black Star No. 2 lead-zinc orebody and the 650–750 copper orebody.

The lead-zinc and copper ores are well known to be of sharply different form and sulphide metal content and correspond closely to the banded pyritic sphalerite-galena and vein-type chalcopyrite-pyrrhotite-(pyrite) ore types defined by the author in earlier papers. The host rocks of the lead-zinc ores have been described as highly ordered, finely bedded dolomitic carbonaceous shales while those of the copper ores are disordered, variably veined and deformed carbonate-rich rocks known as 'silica-dolomite'. Apart from minor to trace quantities, copper and silver-lead-zinc are segregated completely into the two ore types.

The two host rocks are shown to be constitutionally closely related, indicating that they were formed at the same time and in essentially their present relative positions. It is suggested that the two were deposited in contiguous zones of sedimentation, the silica-dolomite representing the more shoreward 'limey' member. The present difference in appearance would seem to be due to differences in deformational behaviour, in turn probably due to differences in original form of the carbonate—that of the silica-dolomite more massive and substantially organic (algal?), that of the shales finely bedded and either inorganic or derived from different, and far finer, organisms.

The abundances of sulphide sulphur, copper, lead and zinc, and the mineralogy of the iron, are related to the abundances of carbonate and alumina in the host rocks. Evidence is presented to show that this is a sedimentary rather than a replacement phenomenon, but that the source of the metals was a fluctuating one and hence not the normal trace content of the ocean. Of two possible fluctuating sources—erosional and volcanic—the latter is shown to be the more likely on present evidence. On the basis of such a volcanic-sedimentary origin the segregation of copper from lead-zinc is regarded as a manifestation of two sub-facies within the sulphide facies of sedimentation, and of biological activity within them. Not one, but three depositional processes appear to have operated: sulphide iron, and the major concentrations of copper and zinc, were probably deposited as sulphides in the first place; lead and silver as some other compound—possibly chloride—which was converted to sulphide on or after deposition; minor copper in the lead-zinc ore and minor lead-zinc in the copper ore, by a minor process—probably adsorption—with later conversion to sulphide.

With Broken Hill, the Mount Isa orebodies constitute one of the two major sources of base metals in Australia. They are noteworthy, however, not only for their size but also for their possession of both copper and lead-zinc ores, and they stand out from all other deposits in the country as combined producers of copper, lead, zinc and silver.

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