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CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

GEOLOGICAL SURVEY OF CANADA
TOPICAL REPORT NO. 129

Report on
TECHNICAL CONFERENCE ON TIN
held by the
INTERNATIONAL TIN COUNCIL
LONDON, ENGLAND, MARCH 13-17, 1967
with field trip to CORNWALL and visit to the
TIN SMELTER, BOOTLE, LANCASHIRE

R. MULLIGAN

OTTAWA
1967

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by

R. MULLIGAN

OTTAWA

1967

INTERNATIONAL TIN COUNCIL CONFERENCE, MARCH 13-17, 1967

1. GENERAL

The Technical Conference on Tin was held by the International Tin Council at its Haymarket House address, London, England from March 13 (Registration) to March 17, 1967. It was attended by some 180 delegates from Great Britain, western Europe including Czechoslovakia, southeast Asia, Africa, South America, U.S.A. and Canada. The program included an afternoon visit to the Tin Research Institute and the conference was followed by a two-day tour of the Cornish tin mining area.

At the time of writing, the bound volumes of the proceedings, including papers and discussion have not appeared, and this report is based on notes and references to pre-prints which were provided for most of the technical papers. Duplicates of these have been turned over to Central Technical Files. These papers are in numerical order as given on the list attached to this report.

The conference was very well organized and handled throughout. Oral summaries of papers by the authors, and discussions, were held to close schedules. Simultaneous translation, and listening facilities, for all proceedings were provided in English, French and Spanish.

The papers generally, and discussion thereof, were of high technical quality requiring complete concentration and full-time pre-session study. The response was enthusiastic, especially as several impartial observers remarked, to the geological papers, and discussion was resumed and continued through mid-day intermissions and into the evenings. Although no papers were directly concerned with Canada, and only one with the North American scene generally (Sainsbury and Hamilton, Paper 13), a surprising amount of interest was evinced, and knowledge shown, of occurrences and the geological environment of tin and of mineral deposits in Canada.

The remainder of this report will deal with the following topics: II PROGRAM, III CORNWALL and IV TIN SMELTER, BOOTLE, LANCS.

II. PROGRAM

(see list of papers attached)

The program was divided primarily according to:

(1) Technical matters

(A) Ore-~~drilling~~ dressing technology - Papers 1-5 and 16)

(B) Underground mining, dredging practice, alluvial prospecting including sonar techniques (Papers 6-10, 14, 19, and 20)

(C) Geology (Papers 11-18 and 23)

(D) Mineralogy (Papers 21-22)

(E) New uses for tin (Paper 24)

(2) Work and problems of Mines Departments and Geological Surveys.

Part (1) of Program: Technical Matters

A. Ore-~~drilling~~ dressing technology

Discussion centred around grade limits (.27 lb. cassiterite/cu. yd. being dredged in Malaysia), upgrading and cleaning concentrates, and recovery of fine tin. A paper on recovery of very fine tin from mill tailings in Cornwall, by Marshall (Paper 2), was not pre-printed. Reference to the special techniques and equipment used there is made in the section on Cornwall, below. Mozley (Paper 5) showed slides of the tilting frame gravity concentration, referred to above. Joy (Paper 4, pp. 4-6) discussed experience with the "Ottawa process" of cassiterite flotation, developed by the Mines Branch. In general discussion Hosking emphasized the extreme original fineness of some cassiterite ores, e.g. St. Agnes. Sainsbury pointed out that at York River,

white cassiterite was unrecognized until someone decided to find out what this strange mineral was. A member of Warren Springs laboratory spoke on the technical difficulties in the halide volatilization scheme (cf. Geomet Reactor). Discussions followed about electro- and electro-kinetic separation relating to use of ferrosilicon, effect of P and As on collection of cassiterite, and role of Fe in the cassiterite lattice as a prerequisite to collection.

B. Dredging, Mining, Alluvial Prospecting.

Batzer's paper (6) on Dredging Practice and subsequent discussion were something of a revelation regarding the complexity of problems and sophistication of dredging techniques. Part I (text) of Garnett's paper (7) on underground explorations was not issued. Until this is available it is not feasible to discuss his numerous instructive diagrams in Part II. Papers (8) (9) and (10) on sea-bed prospecting were discussed together. Sargent (10) showed a number of slides of sonic profiles and interpretation, but the diagrams on pp. 4 and 8 of Paper (8) give a general idea, (Geophysic note).

C. Geology

Janečka's and Štemprok's paper (11) is full of general and particular information on the old and important Erzgebirge tin mining region A number of slides were shown illustrating the relationship of granite to tin deposits - normal granites and "tin-granites" - and various types of deposits. The granites are generally poor in beryllium. Much discussion ensued regarding pegmatites and pseudopegmatites - cf. K feldspathization pp. 12 and 13 (tin in both). Pseudopegmatite ore is very similar to that at South Crofty (see topic III Cornwall, below). I had the opportunity on several occasions to discuss this and other matters, including the Krusny Hory tin-bearing skarn silicates (cf. those in Cassiar District)

with Štemprok. Also discussed was gravimetric detection of buried granite cupolas - this is being done in Cornwall too.

Hosking's wide-ranging paper (12) on tin deposits and granitic rocks was especially valuable, in my opinion, in its attack on established and widely-accepted fallacies regarding distinctions between tin-bearing and non tin-bearing granites.

Sainsbury's and Hamilton's paper (13) also covered a broad field but dwelt mainly on the wealth of factual data he has acquired during many years in the Seward Peninsula, Alaska, tin-beryllium area. Among matters discussed were the North American tin-belts. I considered it necessary to correct and clarify the relationship of the Cordilleran tin belt to the Rocky Mountain system in Canada (see Paper 13, p. 27). I also took the occasion to question the implied inherent connection between tin deposits and biotite granites (Paper 13, p. 10). Sainsbury and I found many occasions to compare notes and discuss mutual problems and ideas during the session and a week in Cornwall.

Kloosterman's paper (15) on the newly discovered and economically important (1000 tons cassiterite per year already) tin fields of Rodondia, Brazil, aroused a lot of interest. Discussion was principally concerned with the possible economic threat to established sources, and implications of its similarity to the Nigerian tin province.

Thormann's paper (17) on the Challapata-Caxata zone of Bolivia is very long and comprehensive. The accompanying map, charts, etc. are not yet available, and the short summary itself was presented by Boris Kucevic.

For Evrard's paper (18) on the Symétain, Congo, deposits the illustrations are not yet available. What is known of the deposits - mainly eluvial, apparently, - seems to support the old established granite-cupola theory of tin concentration. It came out in disucssion that much of the

eluvial cassiterite is very coarse. Evrard mentioned a piece that weighed 50 kg.!

Schuiling's paper (23) on tin belts around the Atlantic Ocean and geochemistry of tin belongs in this group. It was a rather unwieldy two-headed effort but quite controversial and aroused much lively discussion especially regarding the reconstructed pre-continental drift tin belts of South America and West Africa. I questioned consideration of the Mesozoic Cordillera Réal as part of an Atlantic tin belt instead of circum-Pacific (on slides - maps and figures not included in pre-prints). I also criticized, on several grounds, the proposal to base the definition of tin belts on analyses of biotite alone.

D. Mineralogy

Singh's papers (21) and (22) were summarized and discussed together. Magnetic cassiterite and trace-element content were especially interesting. Someone from Heidelberg embarked on a long discourse about tin mineralogy in which he confirmed the occurrence of native tin in the Beaverlodge (Sask.) pitchblende ore and said this was the only occurrence of native tin on record.

Visit to Tin Research Institute

The afternoon visit to the Institute at Greenford, Middlesex, was one of the highlights of the conference. The work being carried out is so varied and sophisticated that it was impossible to see everything or to go into many aspects in any depth. However, excellent exhibits were arranged, explanatory sheets provided for most of the current projects at the Institute, and the staff put themselves at the disposal of the visitors for the afternoon. Some of the projects seen dealt with: the determination by X-ray diffraction of iron-tin compounds in tinplate, X-ray fluorescence

measurement of chromium content of oxide films, use of the electron microscope to study the structure of the iron-tin alloy, electrochemical properties of the iron-tin intermetallic compounds, atomic absorption spectrophotometry for the determination of tin etc. in cast iron, chromic oxide passivation treatments for tinplate, temperature-resisting qualities of tin-alloyed cast iron, effect of tin as an alloying element in steel, effect of tin as an aid to deep drawing, role of tin in the continuous casting of bronze, methods of age-hardening bronze, and various studies of chemical-biological relationships and other aspects of formulation and characteristics of organotins.

Some idea of present and projected uses of tin can be had from Hedges' paper (24), and the Institute publishes a quarterly journal, "Tin and its Uses" available in several languages from its eight regional offices.

Part (2) of Program: Work and Problems of Mines Departments and Geological Surveys.

Papers were presented by delegates from Thailand (25), Bolivia (26), Nigeria (27), and Malaysia (28). The open discussion ranged widely from purely technical matters to politico-economic ones, in three languages. Though I found both the French and Spanish speakers quite comprehensible it was difficult to tell what was going on. There were some loaded questions and heated exchanges. Some spokesmen expressed dissatisfaction with foreign technical aid programs. Acknowledgment was made of Canadian technical assistance in Malaysia (Paper 28). Apparently there were to be seven geologists provided by the Canadian government eventually.

III. CORNWALL

Mining and milling of tin-ore in the Cornwall-Devon area has gone on continuously from pre-Roman times to the present and the remains of old stone head-frames, other surface buildings, old diggings and waste dumps

characterize, without dominating, the very attractive countryside. Alluvial mining is not carried on extensively as it was in the past but the two large active mines, South Crofty and Geevor, account for a substantial part: about 1,800 tons/year, or about one fifth of the "free-world" production of lode tin. Production of china-clay from the St. Austell area is also a major industry. The people I fell into conversation with around the country were quite surprised to hear that tin mining was still going on in Cornwall! Technologically the scene is full of contrasts, with the most modern equipment and techniques cheek-by-jowl with what is apparently the most primitive but yet has proven more effective than anything yet devised to do the job. There is a lot more to be learned in Cornwall than there is to be taught, and it would take a long time to learn it all. For the geologist a week is only a teaser - one would need at least a month with a knowledgable guide and some kind of independent transportation.

The organized two-day tour was arranged and very well handled by the Cornish Chamber of Mines, but was necessarily directed to a quick look at things of most general interest, with emphasis on the Cornwall School of Mines and the Holman Bros. works. It was necessary to choose between tours to the South Crofty mine and area north of Camborne, and to the Geevor mine and St. Just - Land's End area.

The South Crofty mine near Camborne is worked from two shafts about a mile (?) apart that are 2,025 feet and 2,280 feet deep with nine levels in use. It is quite dry and very warm underground. It is an amalgamation of twelve old mines which originally produced copper, then tin at greater depth. The output is about 400 tons per day of 1 per cent Sn ore, or 1,000 tons/year of tin concentrate. The orebodies are subparallel fissure veins in a potassic granite containing biotite, muscovite and tourmaline. There are 15 or 20 lodes averaging 4½ feet wide, but the so-called pegmatite lodes - actually a form of

stockwork - are up to 100 feet wide. Mineralization consists of cassiterite with locally some wolframite in quartz with varying amounts of chlorite, tourmaline, arsenopyrite, chalcopyrite, pyrite, fluorite, hematite and numerous other minerals. Some high-grade cassiterite patches and bands are visibly light brown. Štemprok thought the fresh-looking red feldspar in the "pegmatite" ore was second-generation (see Paper 11 - "Feldspathization stage"). The veins stop abruptly at the contact of the granite with the "Killas" (argillaceous hornfels) country-rock.

Sainsbury and I had a second tour of the mine later, through the kind cooperation of the geologist Barry Mathias, and got some good specimen material. Specimens will be turned over to the mineralogical collection after having thin sections, mineral identification, etc., completed.

At Cligga on the north coast are numerous diggings, the remains of old copper mines. Granite ridges parallel with the coast are laced with parallel quartz-greisen veins with tourmaline. Tin was mined in the St. Agnes cusp. The shore-cliff contact zone of the Killas with a granite ridge is pock-marked with holes that were old hand-mining efforts.

St. Michael's Mount in Penzance Bay is a granite cusp cloaked by slate hornfelds and laced by quartz-greisen-tourmaline veins and some aplite and "pegmatite". Veins are parallel to the regional structural trend. Cassiterite occurs locally in the central bands and occasionally wolframite. A few late veins have sulphides including stannite with varlamoffite incrustations. One vein of quartz is bordered by late adularia feldspar.

The Mount is crowned by a castle, originally a Norman monastery. Visible from it are the old marine platforms (400 foot, etc.), drowned in the Pliocene, with submerged forests, peat, etc., and neolithic artifacts.

The second day of the tour started at the Holman Bros. experimental mine - mainly to test and exhibit mining machinery. Some good examples of

elvan dykes cutting granite were seen. They are dark grey with fine granitoid texture and "chilled" borders. The mining museum at Camborne is a fascinating place. "Lunch" provided by Holman Bros. was a gastronomical experience.

A "tin-streaming" plant treats tailings from the South Crofty mine containing about 2 lb./ton (.01%) of tin. Slurry from settling tanks is passed over a series of round frames on which the pulp is gently washed down from a peripheral orifice toward the centre as it revolves around a vertical axis. At the sector of the frame just "upstream" from the feed-point the concentrate is brushed off by reciprocating brushes (made of heather twigs from the nearby moors). The frames are made of pitch-pine which has apparently very favourable surface-tension and electrostatic characteristics to retain the very fine cassiterite (almost all less than 75 microns and predominantly about 10 microns and less).

At the Camborne School of Mines an exhibition arranged by Dr. K.F.G. Hosking featured specimens and thin sections of various Cornish ores and associated rocks. At the King Edward Mine Mineral Dressing Laboratories, operated by the School, current projects included: 1) effect of electrostatic charges and ionized wash water on superpanner efficiency, 2) an Air Float table made by Kipp Kelly (Canada) (air from beneath fluidized bed), and 3) "Table Flotation" in which pulp fed to a Wilfley table is conditioned so that sulfides float over the riffles and only cassiterite and wolframite goes off the concentrate end.

Following our repeat tour of South Crofty mine Sainsbury and I went through the analytical laboratories and the mill. At the laboratory, routine work includes quantitative chemical analyses for tin in concentrations from tailings (less than .01 per cent) to concentrates with 60 per cent tin by five routine methods depending on matrix! Also complete analyses of the concentrates - As, Cu etc.

At the mill a sink-float plant using ferrosilicon slurry gives a 50 lb./ton concentrate which goes to rod mills and rougher tables (50 per cent tin), flotation, magnetic separators for wolframite, and cleaning. A final concentrate of 60 per cent tin goes to the Liverpool smelter and a 20 per cent tin with wolframite concentrate is stockpiled. About 80 per cent of the tin, ranging down to 10 microns, is recovered.

We then joined Professor Davidson's geology field trip party for the next two days. At a diamond-drill site on a gravity anomaly indicating a possible granite cusp, the hole had been cased to 1,000 feet! At the St. Austell china-clay quarries one of the big open pits is about half a mile long and 500 feet deep. The granite, which contains blue tourmaline and fluorite in quartz veins as well as heavily kaolinized seams and fractures is blasted and kaolin recovered by hydraulicking the broken muck. Huge piles of waste, mostly quartz, dominate the scenery. At the Kernick processing plant the slurry goes from settling tanks to CECO filter-dryer banks where the purified kaolin is stripped off automatically at intervals and further kiln-dried.

At the Tregannus china-stone quarry (now abandoned) a fluorite-rich kaolinized granite has mica (muscovite and low-lithia mica) only on fracture surfaces (very low ferromagnesia). Topaz is not obvious but is seen in thin section.

At South Terras is the site of the only mine in England that was worked specifically for uranium. Total production was 130 tons U_3O_8. The Curie pioneer work used this material. Pitchblende, torbernite and autunite occurred with nickel, cobalt and silver sulphides in a barite-rich gangue. It was a stockwork in one of the greenstone belts.

Near Roche a huge quartz-tourmaline dyke that extends for miles forms a prominent precipitous, little, round hill capped by the ruins of a castle. At nearby Tresay's Down a pegmatite dyke formerly quarried for feldspar has large

albite crystals perpendicular to the walls and projecting into the footwall granite. Quartz is mostly in core pods. Tourmaline and a little muscovite are seen locally.

IV. TIN SMELTER

The Williams Harvey and Co. tin smelter controlled by Consolidated Tin Smelters Ltd. is Bootle, near Liverpool, Lancs. My visit was arranged with Mr. Harris, Director of Research, through the good offices of Mr. Fox, secretary of the International Tin Council. As details of the operation are confidential only a general description can be given.

Incoming ore is sorted according to source and type with special reference to deleterious element content and goes through separate parallel sections of the smelter. Calcining ores are first roasted in rotary furnaces which remove most of the sulphur and arsenic and treated further to reduce lead and bismuth. The main smelting is done in reverbatory furnaces using coke as reducing agent and limestone as flux. The products are tin metal and a slag which is essentially a tin-iron-calcium silicate. The tin is further treated to lower its iron, copper and arsenic content. The slag is resmelted with further limestone and coke to produce an irony tin "hard-head", which is recirculated.

The main problems in tin smelting - (1) to keep the tin out of the slag and (2) to get iron and other impurities out of the tin - are mutually soluble only within limits, due to the physico-chemical properties of tin. Tetravalent tin substitutes fairly readily for iron, calcium etc. in silicates. As the free energies of formation of the lower oxides of tin and iron are very similar, reduction of tin from the slag also entails reduction of iron. Thus the low-grade tin ores available at economic recovery levels from complex ores are at a heavy disadvantage compared with high-grade comparatively clean cassiterite from most alluvial sources.

LIST OF PAPERS

Technical Conference on Tin held by The International Tin Council at Haymarket House, London S.W.1. on 14-17 March, 1967.

The Council convened the Conference with two objects in view:

(i) to consider papers on technical problems in tin, particularly in relation to an increased production of tin and a greater knowledge of the resources of tin; and

(ii) to consider papers on the work and problems of Mines Departments and Geological Surveys in the tin-producing countries, particularly with regard to the dissemination of information on technical and related matters.

(1) A survey of recent trends in ore-dressing practice in Malaysian alluvial tin mines by W.K. NG, PhD, BSc, ARSM, DIC (Research Office, Department of Mines, Malaysia)

(2) The recovery of tin from mill tailings, with particular reference to Cornish practice by J.E.F. MARSHALL, ACSM (minerals engineer, Camborne)

(3) Mineral processing of tin ores by MEURIG P. JONES, BSc, DIC, AMIMM (Mineral Technology Department, Royal School of Mines, London)

(4) The recovery of fine tin by flotation by A.S. JOY, BSc, FRIC, AMIMM and J. KIRKUP, AMIMM (Warren Spring Laboratory, Ministry of Technology, United Kingdom)

(5) A gravity concentrator for fine minerals by R.H. MOZLEY, ACSM (University of Bristol).

(6) Some recent innovations in dredging practice in Malaysia by D.J. BATZER, BSc, ARSM, AMIMM (Anglo-Oriental (Malaya) Sdn. Berhad)

(7) The underground pursuit and development of tin lodes by R.H.T. GARNETT, PhD, DIC, BSc (Eng), ARSM, FGS, AMIMM (Chief Exploration Geologist in Spain for the Patino Mining Corporation of Canada; formerly at the Camborne School of Metalliferous Mining)

(8) Off-shore prospecting by L.J. FICK, MSc (N.V. Billiton Mij, The Hague)

(9) Sea bed prospecting by J.C.C. HILL, Assoc. IME, Affil. IMM, MSAME (Alluvial Mining and Shaft Sinking Co. Ltd.)

(10) Sonic profiling techniques for off-shore prospecting of alluvial deposits by G.E.G. SARGENT, ARCS, BSc (Hunting Geology and Geophysics Ltd.)

(11) Endogenous tin mineralisation in the Bohemian massif by Dr. JOSEF JANEČKA and Dr. MIROSLAV ŠTEMPROK (State Geological Survey, Czechoslovakia)

(12) The relationship between primary tin deposits and granitic rocks by Dr. K.F.G. HOSKING, MSc, PhD, MIMM, FGS (Head of the Department of geology and Applied Geochemistry, Camborne School of Metalliferous Mining, Cornwall)

(13) The geology of lode tin deposits by C.L. SAINSBURY AND J.C. HAMILTON (U.S. Geological Survey, Denver, Colorado)

(14) The Bolivian tin mining industry: Some geographical and economic problems by D.J. FOX, BSc, MA, FRGS (Department of Geography, University of Manchester, England)

(15) A tin province of the Nigerian type in Southern Amazonia by Dr. J.B. KLOOSTERMAN (consulting geologist)

(16) Observations on concentrate grade and recovery relations in some mills of Comibol, Bolivia by P.A. WRIGHT, MA, MIMM (Director of the Mining and Metallurgical Research Institute, U.N. Special Fund, Bolivia)

(17) Geotechnic and metallogenesis of the Challapata-Caxata zone of Bolivia by Dr. WALTER THORMANN with the collaboration of Dr. P. LJUNGGREN and ING. M. VIRREIRA and the Servicio Geológico de Bolivia

(18) Geology of the Symétain mines in Maniema, Congo (D.R.) by PROFESSOR P. EVRARD (University of Liège) and G. SCHAAR (mining engineer and geologist)

(19) Mining in the Symétain mines in Maniema, Congo (D.R.) by P. ANTHOINE (mining engineer and geologist) and C. KHARKEVITCH (mining engineer)

(20) The work of Géomines at Manono by the GÉOMINES Company

(21) Tables for the microscopic identification of tin minerals in Malaysia by D. SANTOKH SINGH

(22) Some general aspects of tin minerals in Malaysia by D. SANTOKH SINGH, MSc, DIC, BSc (Acting Principal Geologist, Economic Geology, Geological Survey of Malaysia) and J.H. BEAN, BSc (Acting Deputy Director, Geological Survey of Malaysia)

(23) Tin belts around the Atlantic Ocean by Dr. R.D. SCHUILING (University of Utrecht, Netherlands)

(24) New avenues for tin consumption by Dr. E.S. HEDGES, MSc, PhD, DSc, FRIG, FIM (Director of the Tin Research Institute)

(25) Work and problems on tin in Thailand by the DEPARTMENT OF MINERAL RESOURCES OF THAILAND

(26) The organisation and objectives of the Geological Service in Bolivia by the SERVICIO GEOLÓGICO DE BOLIVIA

(27) Nigeria: Work and problems of the Mines and Geological Divisions by G.N. ONYEMENAM, ACSM, AMIMM (Assistant Chief Inspector of Mines Nigeria)

(28) Malaysia: A note on the organisation and functions of the Mines Department in Malaysia by the DEPARTMENT OF MINES, MALAYSIA

(29) Some problems for Mines Departments and Geological Surveys in the exploration for and assessment of tin deposits by the SECRETARIAT OF THE INTERNATIONAL TIN COUNCIL