

The Rio Tinto Enigma — no more

The ancient mine workings and slag heaps of Rio Tinto (south-west Spain) have often been described in the literature (Nash; Salkield; Avery; Rothenberg-Blanco) and some of its important ancient mining relics are exhibited in major museums of Spain and abroad, including the famous Roman water wheel shown in the British Museum. It was mainly the huge scale of these workings and the enormous slag heaps which made Rio Tinto unique in the world history of mining and metallurgy. These slag heaps were first surveyed and sampled in 1924, when the Rio Tinto Company issued its 'Map of the Ancient Slag Heaps', including chemical assays and an estimate of the quantity of slag in Rio Tinto: 15,300,000 tones of lead/silver slag and 1,000,000 tons of copper slag. These were astonishing figures and Rio Tinto was generally acknowledged as the largest metal producer of the ancient world, although some authors expressed their amazement that such a huge Imperial Roman production centre of silver should not be mentioned in classical literature.

The classification of the slags as copper or silver slag was based on the following criteria (Salkield 1970, p. 88): slag with more than 0.5% copper and little lead and silver was defined as copper slag; slag with more than 0.5% lead and some silver and little copper was labelled silver slag. Because of the huge quantities of lead/silver slag and because some lead ores had been found between the upper oxidized zone ('Gossan') and the massive pyritic ore body, it was concluded that early Rio Tinto was basically a lead/silver smelter.

The ancient silver and copper ores of Rio Tinto

The geologist David Williams (Royal School of Mines, London) revealed in 1950 that at Cerro Colorado (the main ore body of Rio Tinto) gold and silver ores were overlaying the

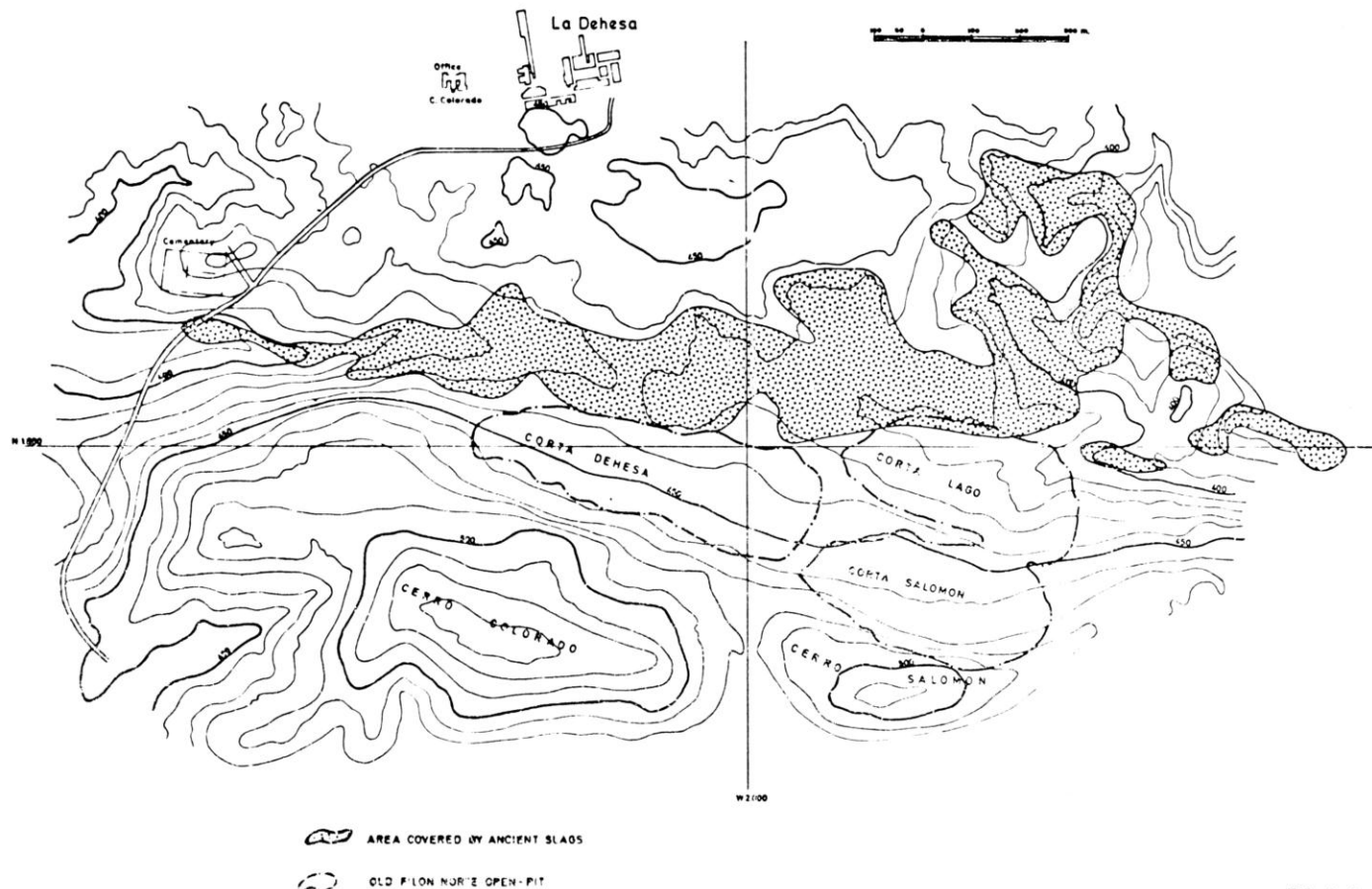
pyrites and he called these 'jerosites'. He estimated that from the Rio Tinto ore bodies about 2,000,000 tons of jerosites were extracted in ancient times. As it was also assumed that in ancient times only copper ores with 8–20% copper were smelted, the source of the copper ore was identified as the chalcolithic ores also contained in the same 'secondary enrichment zone' between the gossan and the massive pyrites.

The date and nature of the slag heaps of Rio Tinto, i.e. the kind of metal produced and at what periods, was frequently discussed in the literature and it became generally accepted that Bronze Age Tartessians began silver production in Rio Tinto on an industrial scale, enhanced soon afterwards by seaborne Phoenician metal-traders of the eighth to six centuries B.C. However, because the Romans resmelted much of the earlier Phoenician slags, most of the black slag visible now at Rio Tinto was assumed to be Roman (Salkield, 1970, p. 93).

The Rio Tinto Enigma

Many basic questions remained unanswered:

1. The slags of Rio Tinto, especially the huge ancient slag build-up uncovered by the recent Corta Lago open pit operation, clearly showed very many undisturbed layers of slag on top of each other and many pre-Roman layers could be identified by finds of undoubtedly pre-Roman pottery. Archaeologically there could not have been any Roman resmelting of earlier slag — simply because these earlier slags were still in their original position below the Roman layers. But what was their date and when did it all start?
2. Modern geological surveys (D. Williams and others) showed that there were only about 3,000,000 tons of jerositic ores in the ore bodies of Rio Tinto, of which



Map of the ancient topography of Rio Tinto before the beginning of mining. The later slag dumps and the North Lode open cast mines are also marked on the map.

T. G. Palomero

about 2,000,000 had been extracted in ancient times. It was estimated that about 4500 kg. of slag were produced from 1000 kg. of jerositic ores (Salkield, p. 92). How could 15,300,000 tons of slag be produced from only 2,000,000 tons of ore?

3. Since in the ancient smelting operation about one ton of charcoal was needed to produce one ton of slag, 40,000 tons of charcoal per annum, i.e. 110 tons of charcoal daily, would have been required over a period of about 400 years, to produce 15,300,000 tons of lead/silver slag. Salkield, investigating this problem (1970 p. 94), reached the conclusion that the Romans would have had to cut down 600,000 mature trees per annum — quite an impossible figure.
4. The Rio Tinto slags showed extremely low metal contents: 0.1–0.56% Pb in silver slag and 0.6–0.9% Cu in copper slag according to the R.T.M. assay in 1924 — as compared with ancient slag elsewhere: at Laurion, Greece, 10% Pb; in Sardinia up to 30% Pb; at Cartagena, Spain, 8–17% Pb; in Timna, Israel, 4% Cu in Bronze Age slag and up to 17% Cu in Chalcolithic slag. This surprising fact was often explained as the result of a highly advanced smelting technique known to the Romans and unknown to us (already suggested by Ramon Rua Figueroa in 1859).

Sorting out the archaeological history of the Rio Tinto slag heaps

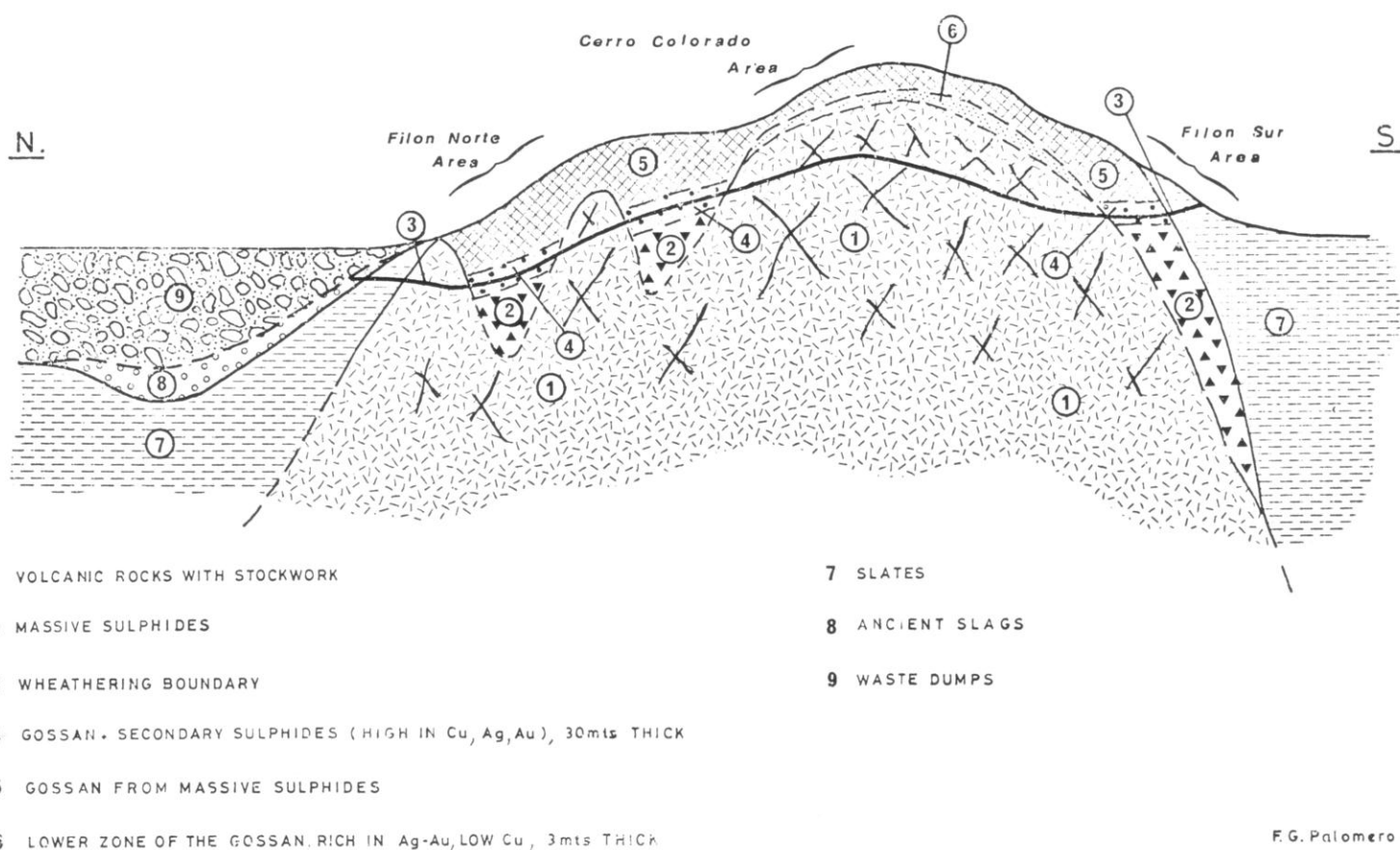
Eight seasons of excavations in the slag heaps of Rio Tinto by the IAMS team, lead by Beno Rothenberg (IAMS Newsletters Nos. 1, 2, 3) produced a fascinating picture of its history. After initial prehistoric beginnings in the Chalcolithic Period (Early Copper Age of Spain, perhaps as early as the fourth millennium B.C.) proper industrial mining and silver

production began next to a small spring on the northern slope of the huge Cerro Salomon, today the Corta Lago open cast mine. Here a 10-metre high slag section was exposed by modern mining and its more than one hundred superimposed slag layers could be dated by pottery and coins. Further systematic trial trenching over the entire slag area has shown the gradual growth, in almost perfect eccentric circles, of the smelting operations from a small Late Bronze Age (late second century B.C.) smelters' habitation to the huge metal industry of Imperial Rome (into the second century A.D.).

Moreover, two surprising new basic facts became clear during this archaeological survey which cast serious doubts on the previously commonly accepted concepts of Rio Tinto and its 15,300,000 tons of silver slag. The slag heaps were found to be of rather varying depth, i.e. from a very thin cover on originally high ground (see the original topography of the site above) to 15-metres and more of slags dumped into deep valleys. Further doubt arose when the first analyses of the slag samples from the Corta Lago Section became available (Rothenberg-Blanco, 1981, p. 105). Though the pre-Roman layers showed that only silver was produced during these periods, the Roman layers revealed that copper had, by Roman times, become a main product of the Rio Tinto workings. The Rio Tinto Enigma, though still rather confusing, began to crack, but it took several years of further investigation using modern research methods to finally sort things out.

A new look at the slag heaps of Rio Tinto, 1983–85

As a result of our archaeological investigations, the systematic survey in depth of the ancient slags had become imperative and this was carried out by Rio Tinto geologists, directed by Felix Garcia Palomero, in the course of their general re-investigation of the gossans of Rio Tinto. After three years of a computerized drilling programme, which covered the entire



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Schematic section through the Cerro Colorado mineral bodies showing the location of the silver and copper ores extracted in antiquity.

slag area by a narrow net of drill-holes down into the bedrock below the slag layers, it became possible to define for the first time the real volume and composition of the entire slag build-up of Rio Tinto and to establish the different sources of the copper, silver and gold minerals used by the ancients to produce their metals and the slag heaps.

How much and what kind of slag?

The slag dumps of Rio Tinto, covering about 2500–200 metres, turned out to have an average thickness of six metres, which means a total volume of 6,000,000 tons instead of the previously (1924) estimated 16,000,000 tons of slag. This greatly reduced slag volume obviously lowered the estimated quantity of charcoal needed for the smelting operations to a far more reasonable figure.

Furthermore, the new survey found two basically different kinds of slag all over the slag heaps: a silver smelting slag with a very low copper (less than 300 p.p.m.) and a high lead (1.2%) content, and a slag with a very high copper content (more than 1000 p.p.m.), which was obviously the product of copper smelting.

Different sources of silver and copper

The schematic Cerro Colorado Section indicates a different location of the copper and the silver ores within the Rio Tinto ore body. The copper ores came only from the 'secondary enrichment zone' between the gossan and the massive sulphides (Section N.4) whilst the jerositic silver ores, with only low copper contents, came from the lower parts of the gossan, above the level of the copper concentration (Section N.6). The now well defined total volume of these ores corresponds very well with the 6,000,000 tons of copper and silver slag established by the new archaeological and geological survey.

The new drilling programme also helped to solve the riddle of the extremely low metal content in the copper smelting slag, previously often assumed to be the result of a highly efficient Roman copper smelting process unknown to us. There can now be little doubt that the low metal content of the ancient slag of Rio Tinto is the result of a continuous strong leaching process, which brought about the removal of most of the copper and some of the silver and gold. The analyses of the bedrock below the slag showed some re-deposited silver and (less) gold in its upper 2–4 metres, whilst the copper, due to its higher solubility in water, migrated to an even greater depth.

The Rio Tinto Enigma, repeatedly argued by several generations of investigators, has now been resolved through the strictly problem-related archaeo-metallurgical research methods developed over the years by IAMS.

The detailed report on the new Rio Tinto discoveries will shortly be published by Beno Rothenberg, F. Gracia Palomero and H. G. Bachmann.

Beno Rothenberg,
Felix Gracia Palomero

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The huge slag section at Corta Lago with its major slag layers labelled for dating and slag sampling. Its time span runs from the Late Bronze Age (at the bottom) to Imperial Rome (upper section).

Rio Tinto Mining Museum

The major theme of this unique mining museum is the history of Rio Tinto and the development of the various metallurgical processes which are represented in the spoil heaps, slag heaps and installations, ancient and modern.

The Mining Museum of Rio Tinto is housed in the former Mine Hospital building in the village of Minas de Riotinto. It will tell the story of mining and metallurgy in Rio Tinto from very early prehistoric times and will present, in an integrated manner, two parallel major subjects:

- 1 The archaeological and industrial archaeological sites in Riotinto.
- 2 The developments of mining and metal production technology through the ages.



The refurbished hospital building – now the Rio Tinto Mining Museum

The story of Riotinto will, in fact, write a new history of Europe's metallurgy of sulphide orebodies. Based on many years of exploration and excavation in the field and thorough metallurgical, analytical and experimental studies, we can today reconstruct the metal history of Riotinto on a sound scientific and archaeological basis. This will reflect the history of metallurgy, its techniques, problems, developments and achievements.

The present plan of the Museum contains the following sections, each to be housed in a separate room:

1 PREHISTORY: The earliest evidence for prehistoric production and use of copper and silver in Rio Tinto; the dolmen and early cist burials in Rio Tinto.

2 THE BEGINNING OF COPPER MINING AND SMELTING: Third millennium B.C. mineworkings, perhaps starting in the fourth millennium, the earliest copper smelting technology in Western Europe.

3 CORTA LAGO — FROM LATE BRONZE AGE TO THE ROMANS: Industrial mining and smelting of silver, copper and iron.

4 THE ANCIENT METALLURGICAL PROCESSES: The development of silver, copper and iron smelting technology in ancient times in Riotinto.

5 THE ROMANS IN RIOTINTO: Mining, metal production and industrial organisation —

Part 1 Roman mining

Part 2 Roman building technology, metal working, pottery and glass. Cultural and social aspects of daily life

Part 3 Excavations in Riotinto

6 GEOLOGY IN RIOTINTO:

Part 1 Genesis of the orebodies

Part 2 Mining potentials of the different orebodies with emphasis on ancient as well as modern technologies

Part 3 Ores mined in various periods

7 THE BEGINNING OF MODERN COPPER PRODUCTION IN RIO TINTO: Sites, installations, technologies and people.

8 UNDERGROUND AND OPENCAST MINING:

Part 1 Opencast mining: techniques; equipment; transport and people

Part 2 Underground mining

Part 3 The production of copper: Concentrator, smelter, products, flowsheet of processes

9 PRESENT AND FUTURE: Mining in Riotinto today and tomorrow; Opencast and underground; From ore to finished product; Flowsheets and Processes.

10 THE LIFELINE OF RIO TINTO: The history of the Riotinto railway and the mainline transport.

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University of Palma de Mallorca (Spain)

Dr Noel Gale,

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