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TUNNEL LINING AT RIO TINTO: METHODS USED AT LAS MINAS DE RIO TINTO, IN SPAIN, 1954

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Foreword: In the summer of 1952 the author, then aged 20, graduated B.Sc. (Eng) in Mining Engineering from the Royal School of Mines, London. Soon afterwards, he was called up to serve two years' National Service in the Army with the Royal Engineers. After basic Field Engineer training, he was posted to the Tunneling Troop, Fortress Engineering Regiment, on Gibraltar. Towards the end of his time there he managed, despite a general ban on leave into Spain following the Queen's visit to Gibraltar in May 1954 at the end of her tour of the Empire, to obtain permission to spend a fortnight's leave visiting the Rio Tinto mines in Huelva Province. He was at Rio Tinto from July 26 to August 7, staying as the guest of L.A. (Sandy) Hill, then in charge of the Alfredo underground section. He visited a different section of the mine each day - open-pit, underground, concentrator and smelter.

In Gibraltar, earlier in the year, Tunnelling Troop had succeeded in holing through a tunnel which, in its closing stages, had been driven through bad ground. It was planned to line parts of this tunnel with concrete, the author being designated to be the NCO in charge. Thus it was that, during the visit to Rio Tinto, the tunnel lining methods in use were of particular interest, and the report presented here was written on his return, being dated August 11, 1954.

After scrutiny by the Tunnelling Officer, Captain Jackson, the report was filed away and forgotten until it was rediscovered, in July 1999, in the author's attic. Itself already 45 years old, it describes in some detail a tunnel lining method which must long ago have been consigned to history. As the inner lining of the tunnels in question present the appearance of smooth concrete, their method of construction may not at first sight be obvious. A literature search in the library of the Institution of Mining and Metallurgy has failed to find any previous description. This is thus thought to be the first published account of how the Rio Tinto tunnel linings were made.

The Atalaya open-pit, Rio Tinto - served by rail tunnels.

TERMINOLOGY

Some terms used in the report are not in general use, although they were the current practice at Rio Tinto at that time. Thus the open-pit mines were referred to as open-casts, a term which nowadays is more commonly reserved for strip mining. In the report, as presented here, the original wording has been changed to "open-pit" to bring it into line with modern practice.

The underground mining method then in use at Rio Tinto was a possibly unique form of bottom slicing, sometimes called horizontal cut-and-fill. In this manually intensive method, as successive levels were worked, a depth of about eight feet of ore was mined out over a limited area and the space back-filled to the roof. As successive levels were extracted, working upwards, the fill compacted and the block of ore was required to settle downwards onto the fill without fracturing unduly. To do this the ore needed to move relative to both near-vertical footwall and hanging wall contacts. The massive pyritic orebodies trended east-west and, for mining purposes, were divided into "blocks" measuring about 300 to 375 feet long by transverse cut-and-fill stopes across the width of the orebody, which ensured that the ends of each "block" were free to settle.

The southern contact was with slate. Here, the margin of the lode was sharply defined, with the slaty cleavage generally running parallel to it. There was, in consequence, nothing on this boundary to prevent a steady settlement of the block of ore once mining had commenced, and this boundary was described at Rio Tinto as being "free".

The northern contact between the massive pyritic orebody and the surrounding porphyry was, on the other hand, one of intergrowth - in some zones there was sufficient disseminated chalcopyrite in the porphyry to make it economic to mine. There was thus no chance of free settlement of the ore along the northern boundary, which at Rio Tinto at that time was referred to as "frozen". The usual remedy was to put up a preliminary narrow cut-and-fill stope along the ore/porphyry contact to "free" the ore, so that even settlement could take place.

These terms, "free" and "frozen", although unusual geological terms, were thus then in use by mining engineers at Rio Tinto.

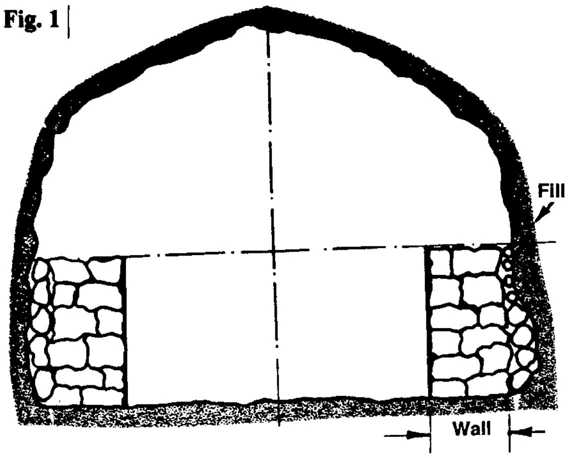
Fig. 1


Fig. 1. A cross-section of an excavated tunnel, showing the lower walls in place.

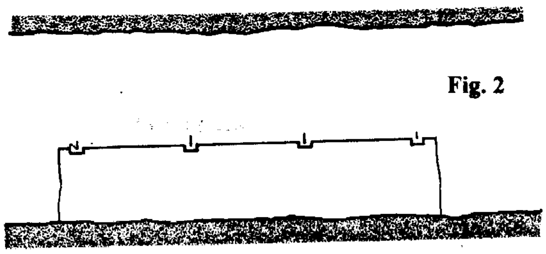
Fig. 2


Fig. 2. The location of notches in a wall along the side of the tunnel.

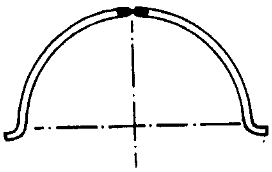


Fig. 3

Fig. 3. A steel former assembled.

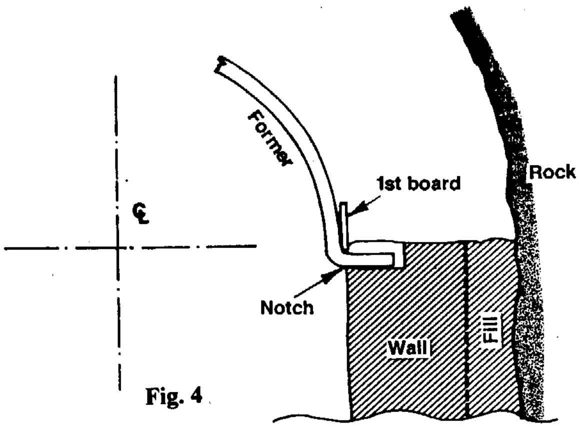


Fig. 4

Fig. 4. Showing the location of the first board behind the former, its inner face in line with the top of the lower wall.

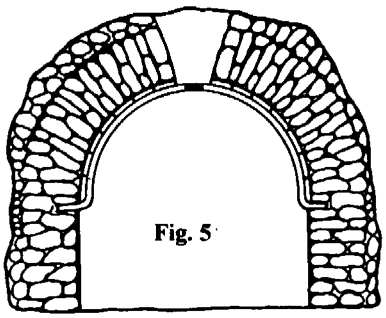


Fig. 5

Fig. 5. The state of construction at the end to Stage Three, that part of the construction using longitudinal boards.

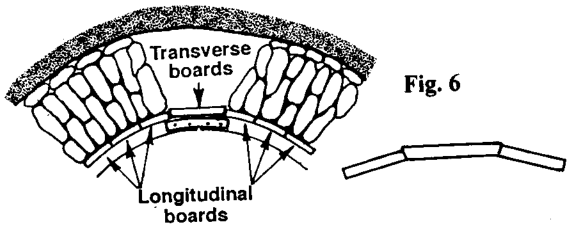


Fig. 6

Fig. 6. The location of the short transverse boards, enabling the crown section to be built. (The detail to the right shows how the short transverse boards are supported by the topmost longitudinal boards).

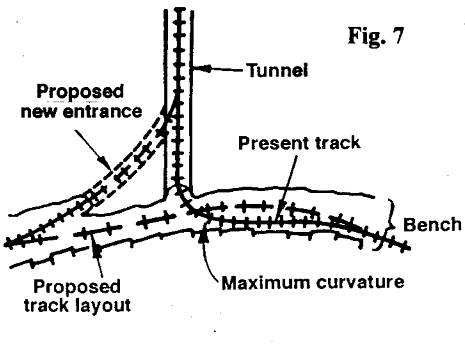
Fig. 7


Fig. 7. A plan view of the existing and planned track arrangement at the entrance to Tunnel 3.

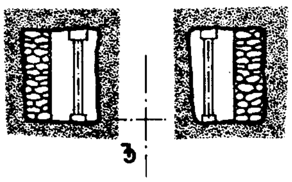


Fig. 8

Fig. 8. A section through the twin tunnels, driven along the sides of the proposed new rail tunnel.

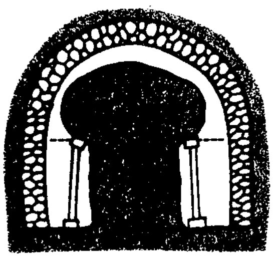


Fig. 9

Fig. 9. A section through the partially-excavated new rail tunnel, showing the lining completed before all excavation had been carried out.

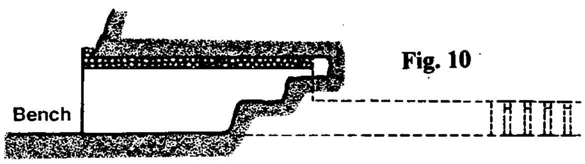


Fig. 10

Fig. 10. A longitudinal section through the new rail tunnel, indicating the stages of construction.

TUNNEL LINING - RIO TINTO MINES METHOD

Summary: The method of lining tunnels in poor ground, as used at the Rio Tinto mines over many years, is given in outline.

Geology

The main orebody at Rio Tinto is of massive pyrite with an east-west strike, tapering in depth. The north contact is a frozen one with a porphyry rock containing disseminated chalcopyrite. The south contact is free, the country rock in this case being slate. As this contact crops out on the surface it is wet, and the slate has in places degenerated, resulting in bad ground south of the lode.

Arrangement of workings

The main orebody broadens out on the west, and is there worked by open-pit methods. On the east it is worked by underground cut-and-fill stoping. All shafts are in the porphyry, while return roads for ventilation are in the slate. As the ore slowly oxidises in the stopes, heat and SO_2 are generated, and a good ventilation system must be maintained to permit working there. Return airways must be soundly made, as any repair work needed must normally be done by men wearing gas-masks, and the need for such work thus involves more expense than usual maintenance costs.

Tunnel linings

Application:

The method of tunnel lining in bad ground used at the mine is standard in principle for all types of tunnel that may require it – ventilation roads, mine haulage roads, or railway tunnels connecting with the open pit.

Materials:

All stone for fill and building purposes underground is obtained from the porphyry side of the open-pit where possible. Slate may also be used for fill, but never for building. Building stone is sorted out by hand on the benches of the open pit and tipped down special stone passes into the adjoining underground workings. The sizes of stones used for building vary, and the shapes are quite irregular. The smallest are about the size of a common brick, the largest about three times the size of the smallest.

Cement is taken underground in bags and stored as near as is convenient to the construction site. Sand for mortar is usually fine fill, obtained from appropriate fill passes. All work sites throughout the mine usually have a piped water supply, and compressed air is also available if required.

In the method of lining used, rings made of old rails, and planks for shuttering, are needed. These are not expended and may be re-used repeatedly.

Lining construction

Tunnel size:

When it has been decided that a section of tunnel needs lining, it is driven or widened if necessary to a width of at least one metre more than the final width desired inside the lining, and to a height of at least 0.5 metre more than the final height desired. The roof may be roughly arched during this process.

Construction – Stage One

The lining is normally built in lengths of up to 5 metres. The first stage is to construct walls along each side of the tunnel up to half the height of the final tunnel section. The walls are made 0.5 metres thick, and extra space being filled as the wall proceeds: see Fig. 1.

The inner faces of the walls may be kept true by building up a shuttering one plank at a time as construction proceeds, the final effect being a face with all the appearance of concrete.

Alternatively, the wall may be built rough, and given a facing of mortar.

At four places in each length of wall notches are left about 20 cm wide and 10 cm deep [from the front edge]. The notches face each other in pairs, equally spaced apart: see Fig. 2.

Construction – Stage Two

Arched formers, made out of old rails in the mine workshops, are now assembled and placed in the notches. Each former is made of two parts fish-plated together. The rails are bent with the sole outwards, and the formers are made in standard sizes to suit the common sizes of tunnels to be lined.

Fig. 3 shows a former assembled. The lower limbs of the arch are bent back, and these parts are ledged on and wedged into the notches on the side walls. The formers are spragged against the roof temporarily to prevent them collapsing whilst construction proceeds.

Construction – Stage Three

Once the formers are in place, masonry work can proceed. A board, about 20 cm wide and 3 to 4 cm thick, and 5 metres or so long, is laid behind the formers, its outer face flush with the top of the inside face of the existing wall, as shown in Fig. 4.

The wall is then continued upwards the height of the board, care being taken to cover the notches with suitable flat stones, so that the notches are left open and the formers left free for later extraction.

As walling approaches the top of the board, another board is laid edgewise on it, leaning on the former, and so on as construction progresses – see Fig. 5.

Construction—Stage Four

The final stage in construction is to build that part of the lining which forms the key in the crown of the arch. The space between the two highest longitudinal boards is of the order of 30 cm. This is bridged by short transverse boards. These are placed two or three at a time, and the masonry and fill which forms the key laid on them. The key is thus built from one end of the section to the other.

The transverse board are supported by the two highest longitudinal boards, as shown in Daigram 6.

When the mortar has had sufficient time to set, the formers and boards are removed, and the notches filled in.

A lining of this type is known as a "*Bóveda*". Some *bóvedas* are still in good condition after standing about 40 years.

Tunnel No 3 *Bóveda*

The majority of *bóvedas* have a finished internal size of 2 x 2 metres, and are erected in tunnels in which excavation is complete. In one instance, however, a *bóveda* 4 x 4 metres is being made, the bulk of construction being done before [complete] excavation. A brief description of this follows.

Location

On the "Tunnel No 3" level of the open pit – about the ninth floor of the mine – is a tunnel carrying a three-foot gauge railway through which waste rock is carried to dumps in a nearby valley. The bench is fairly narrow, and has further material to be removed from it. The existing track is already at maximum curvature, so a second entrance to the tunnel is to be made, as shown in Fig. 7.

The ground in which the new drive is to be made is degenerated slate, easily broken with a hand pick, which will not stand over a span of 5 metres long enough for a *bóveda* to be constructed in the usual manner.

Method

Starting in the existing tunnel, two small drives were put in along the lines of the side walls of the new tunnel, using timber support. After holing through into the open pit bench, masonry walls were built in them, and the timbering removed, starting at the bench and retreating to the tunnel. Fig. 8 shows a section of these twin tunnels.

After the side walls had progressed sufficiently far, entrance was made from the bench, excavating material to make room for the arch of the *bóveda*. The arch itself was kept within a metre or two of the excavation by constructing it in short sections. When the mortar in the arch had set, excavation of the centre portion of slate continued. The bulk of the excavation of the finished tunnel was thus done under the cover of the permanent support. Fig. 9 shows a cross-section with the arch in place, and Fig. 10 a longitudinal section showing all stages of construction of the *bóveda*.

REFERENCES

The following references containing relevant information have been found (July 1999) in the library of the Institution of Mining and Metallurgy, London:

Williams, David 1934 The Geology of the Rio Tinto Mines, Spain. *Trans IMM*, Vol 43 (1933-34), pp.593 et seq. (*Bulletin* 355, April 1934).

Note: Williams, Professor of Geology at the Royal School of Mines was Chief Geologist at Rio Tinto.

Julian, C.R. 1940 Underground mining at Rio Tinto, Spain *Trans IMM*, Vol 49 (1939-40), pp.237 et seq (*Bulletin* 421 October 1939).

[Note: Julian was the Chief Mining Engineer at the Rio Tinto Mines. His paper uses the word "frozen" in the sense described above. For example, on page 245, para 3, it reads: "In those stopes where the contact is such that the pyrites is frozen to the porphyry footwall, . . . uneven settlement will occur since the ore will not break away freely from the porphyry."]

Pryor, R.N. 1960 Mining of Cupreous Stockwork Ores at Rio Tinto, Spain *Trans IMM* 69, 1959-60 pp661 et seq (Bulletin 646, September 1960*)*

Note Prior was Chief Mining Engineer, Cia Española de Minas de Rio Tinto, S.A.)

Although Julian makes reference to ventilation tunnels being "concrete lined", and some haulage tunnels through fill being "maintained through the filling by building masonry arches about 7 ft. high and 5 ft wide", no details of how the masonry arches were constructed are given in these papers.

To check on the accuracy of the report, the author sent a copy in July 1999 to the former Rio Tinto mining engineer who was his host during the 1954 visit, the aforesaid Mr. L. A. Hill, FIMM, now living in Norfolk. His only comment on the contents was to circle the point on Fig. 7 showing where the proposed new entrance joined into the existing rail tunnel, appending the remark "The tricky bit!!"

Gibraltar 11th August 1954
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