THEN, THERE WERE MINES

Volume
1

Margaret Davies

2020

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From 'Minas de Almagrera S. A. 1944-58. Andrés Sánchez Picón & Isabel García Jiminéz

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Chapter 1. The Sierra Almagrera

1.1. The geography and geology
1.2. The wealth of minerals and the mineral's wealth

Part 1. The geography and geology.

The Sierra Almagrera.
Club de Montaña. Desamparados.

The Sierra Almagrera is a small mountain range in the Province of Almería. It runs parallel to the Mediterranean coast from Villaricos to Pozo del Esparto, the coastal border between the Provinces of Murcia and Almería. A mere 12 kilometres in length, 4 kilometres in width and with a highest point at 367 metres, the Sierra Almagrera is one of the many ranges within the internal, southern zone of the Baetic Cordilleras.

The Baetic Cordilleras comprise the Andalusian mountains of south-eastern Spain. There are two distinct zones, the northern, external zone runs from Cape Trafalgar in Andalusia to Cape Nao in Valencia, and continues in submerged form to the Balearic Islands. The southern, internal zone runs from Estepona in the Province of Málaga to the Mar Menor in Murcia Province.

The geology of the two distinct domains of the Baetic Cordilleras.

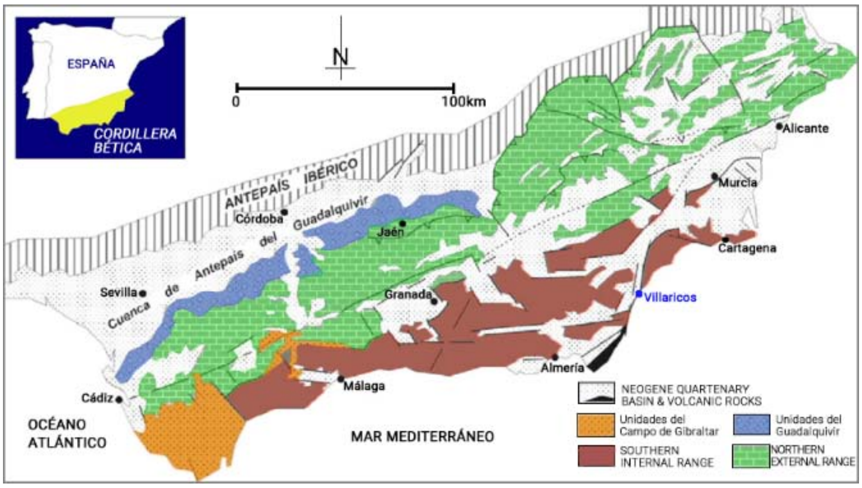
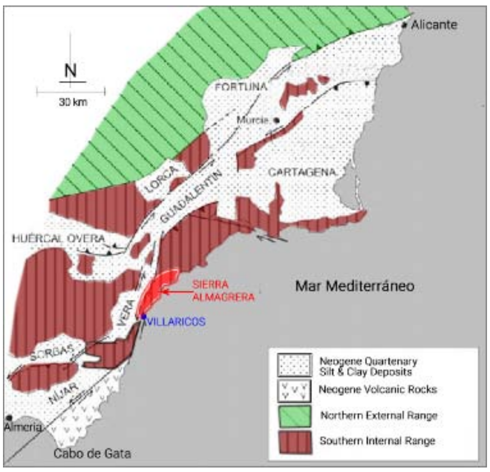
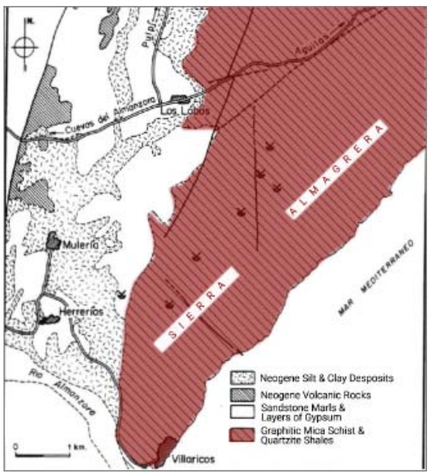


Diagram (right & below left)
Registro de eventos del Messiniense y Plioceno Soria,
Corbí et al.



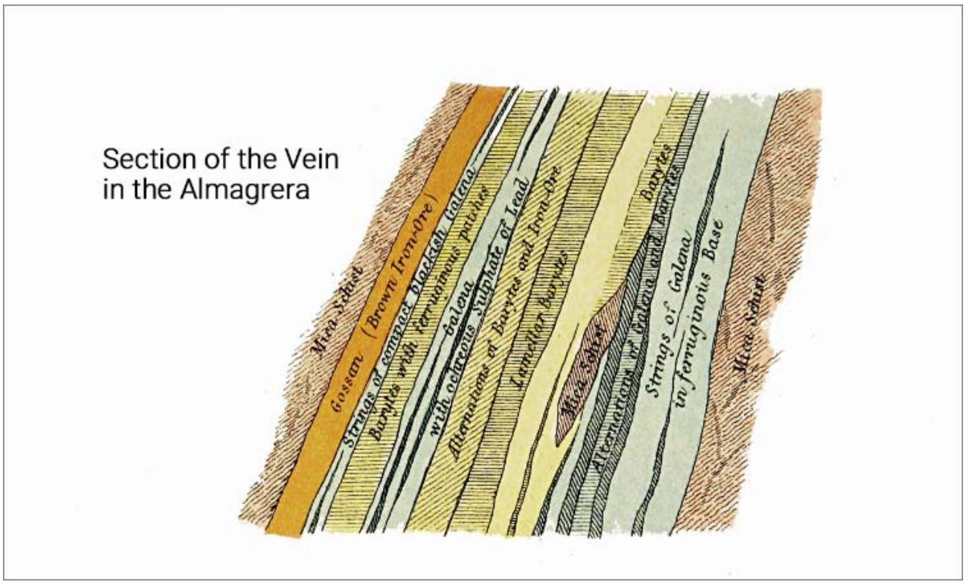
Left, focusing in on the Sierra Almagrera.

Right, the geology and position of the deposits of the Sierra Almagrera and the Las Herrerías basin.
Guinea and Ruiz



The Sierra Almagrera appears, on the surface, to be an insignificant part of this massive belt of mountains, but in its day its punched well above its weight. A closer examination of the geology of the area gives a clue as to why. The Sierra was formed between 54 million and 25 million years ago during the Paleozoic era, a period of great change when whole continents were breaking up and new ones being formed. It consists of metamorphic rocks which arose when the existing rock types were subjected to high temperatures, greater than 150°-200°C, and pressures greater than 1500bars (21756psi), forcing them upwards.

A look inside a single vein in the mountain shows its riches. Hidden beneath the mica schist and slate is a wealth of valuable minerals, ores associated with a geothermal system. Galena, zinc sulphide, copper sulphide, pyrites, haematite, barite and jarosite to name a few.



Vein in the Sierra Almagrera. Simonin.

The easiest rock to recognise is the slate which is underfoot as you climb up the mountains' tracks, where clear examples of foliation or pleating can be seen. Evidence of the great forces that formed the Sierra can be seen when the slate is cut into, revealing mineral veins which have been thrust upwards.

Pleating, or foliation of the slate.

A vein of quartz pushed upwards through the slate.

The colour of the rock means that there is no mistaking the presence of iron in the area shown below.

A localized outcrop of iron ore.

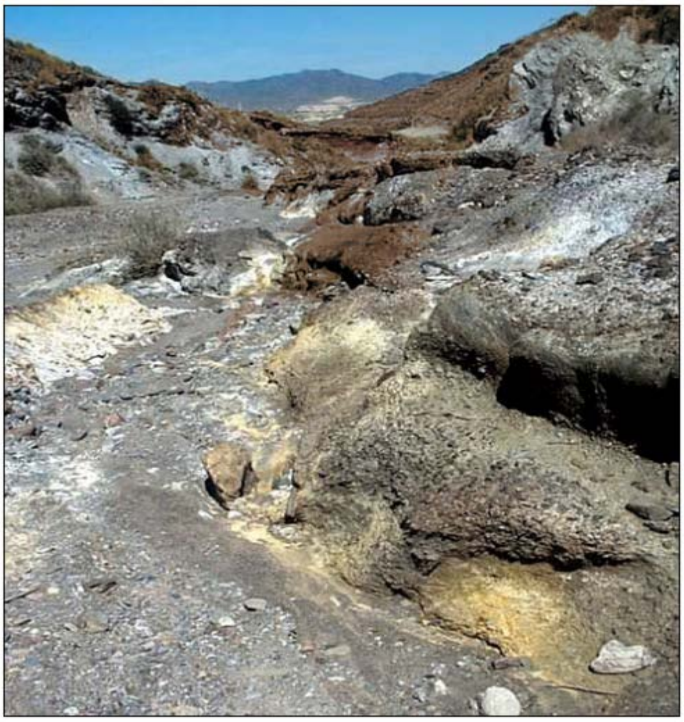
Below, an "iron curtain" is draped over the sandstone marl at the foot of the mountain.

The galena (lead sulphide) was mined here as early as 3000B.C. The Phoenicians and later, the Romans, delved into the mountainside. The Roman mine at El Arteal could be explored until quite recently, but now only a short part of the entrance gallery is passable. Even so, that is sufficient to make you marvel at the quality of their workmanship. The gallery roof and sides look as if they have been excavated by machine.

The entrance and gallery to the Roman mine.

What really put this area on the map, was the discovery, in 1839, of Argentiferous Galena. That is lead ore with a small percentage, typically 1-2%, of silver. Despite its low percentage, the silver by-product far outweighed the lead in terms of revenue. With the 1-2% silver worth 300 times more per tonne than the 80% lead in the ore per tonne, the resulting Silver Rush wasn't surprising. In a short space of time the entire Sierra had been demarcated and registered. In all, 1,700 shafts were sunk. Not all of these were exploited.

The area is also famous for the discovery and naming, in 1852, of potassium/iron hydrous sulphate by August Breithaupt. He called this new, yellow mineral Jarosita (Jarosite) after the barranco where he discovered it, called the Barranco del Jaroso. The barranco itself was named after the hundreds of yellow Jara, or rock rose bushes that grew there. While much of the Jaroso valley remains a contaminated wasteland of spoil tips and tailings, Jara is making a comeback.
In May, especially after a wet Spring, many slopes are once more carpeted in its yellow blooms.



The effect of contamination in the Barranco del Jaroso.

The Jara or rock rose that gave the Barranco del Jaroso its name.

Water is needed to form Jarosite, so when it was discovered on Mars in 2004, it was concluded that water must have been present at some time in that planet’s history.

Part 2. The wealth of minerals and the mineral’s wealth.
The first question was, what were they mining? The second was, why? These are some of the facts mined from Wikipedia.

Galena. (lead sulphide)
This is the principle ore of lead. It can contain copper and zinc, both of which have been exploited in the Sierra, where it also contained silver. Its low melting point makes it easy to smelt, giving off Sulphur Dioxide.

The Ancient Egyptians used galena to make kohl, which they put around their eyes in order to mitigate the glare of the sun and to repel flies.

As it is a semi-conductor, galena was the crystal in the old “crystal” radio where it was used as a point contact diode to detect radio signals. The “cat's whisker” was a galena crystal on a safety pin or a piece of sharp wire.

Cat's whisker radio receiver.

The use of lead in paints, pottery glazes, petrol, solder, ammunition, fishing weights, pesticides, cosmetics, glass and plastics has been virtually discontinued due to its toxicity. However it is still used in batteries and lead shot, also, lead sheet is still obtainable.

The Romans used lead for pipes. “plumb” is Latin for lead, hence plumbing and plumber in English. They produced bars of lead stamped ‘*ex arg’, or de-silvered,* to indicate that they had extracted any silver from it.

Haematite. (iron oxide)
The rusty-red iron ore. The driving force behind the Industrial Revolution and beyond. The raw material for steel. Its uses and applications are too numerous to mention. The haematite in the Sierra and at Las Herrerías was of such good quality that it needed the minimum amount of processing and was the source of great wealth at the end of the 19th and beginning of the 20th centuries.

In these rock samples the white is quartz, the black is galena and the rust-coloured is pyrite.

Pyrite. (iron sulphide)
Fools' Gold. The name pyrites is from the Greek meaning “of fire” a reference to the fact that it sparks when struck against a steel. It was used in early firearms.

Crystals of pyrite, often set in silver, were used to make Marcasite jewellery, (which does not contain any marcasite). Such jewellery was very popular during the years of the local mining boom.

It was also used as a source of sulphuric acid.

Like galena, pyrite is a semi-conductor, and was used in early radio sets. Pyrite wave detectors were as sensitive as modern diode detectors.

Currently, the use of pyrite in photovoltaic solar panels is being studied.

Zinc Sulphide.
Zinc sulphide was used with copper to make brass and was widely used as a pigment and in skin ointments. It is phosphorescent and is used on X-ray and T.V. screens.

Silver.
Silver was found in association with galena which started the Silver Rush. More importantly native or pure silver was found in Las Herrerías.

Barite. (barium sulphate)
Barite is the principle ore of barium. Its name derives from the Greek word “barys” meaning heavy. It is exceptionally heavy for a non-metallic mineral and is used extensively as a weighting filler in paper, cloth and rubber. Playing cards owe their weight to it as do mud flaps on trucks.

It is used as a weighting agent in drilling fluids, or muds, for oil and gas exploration where it suppresses high pressures and helps prevent blow-outs. It is also widely used as a pigment in paints.

Barite is able to block X and Gamma ray emissions so is used to make the high density concrete used for shielding. Barium meals and enemas are used to X-ray image the tissues of the oesophagus and colon.

Opencast mining for barite in Las Rosaz.

Photo J M Germán Celilia.

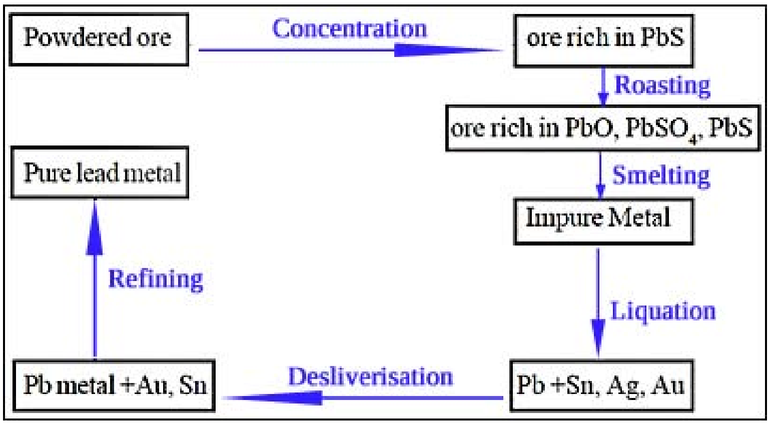
Chapter 2. The Alchemy of Lead Production

2.1. Introduction to the process.

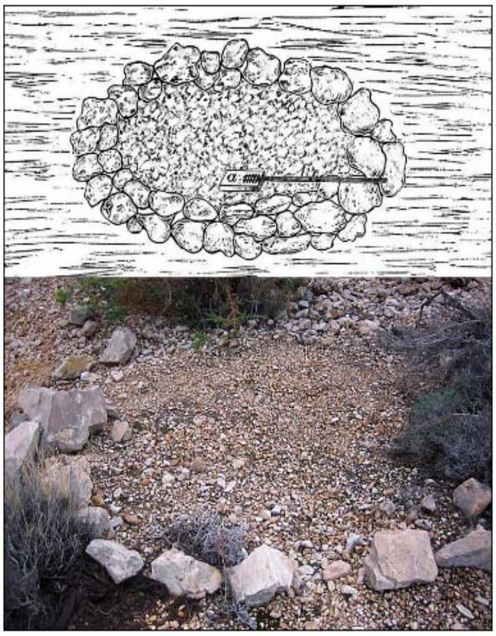
Mining, by its very nature, produces a tremendous amount of waste. Between 65 and 80% of the material extracted in the Almagrera was discarded. Mullock, or overburden, the non-ore bedrock in the mine, can be seen everywhere in the mountains associated with the shafts and workings.

Galena forms by direct precipitation from the hot waters that migrate through the earth's crust. It is associated with quartz, pyrites, barite and various other minerals. These unwanted minerals, that are an intrinsic part of the ore rock, are separated during concentration and are known as gangue or tailings. Where the ore was dressed at the mine this gangue was tipped over the edge of the “patio de minerales”, or dressing yards, into the ravines with little regard for lower workings. These spoil heaps or “escombreras” are very unstable and are best avoided. However, by looking at the size and colour of the pieces they do give clues as to what processes were carried out in a specific place.

Lead is processed in the following main stages.

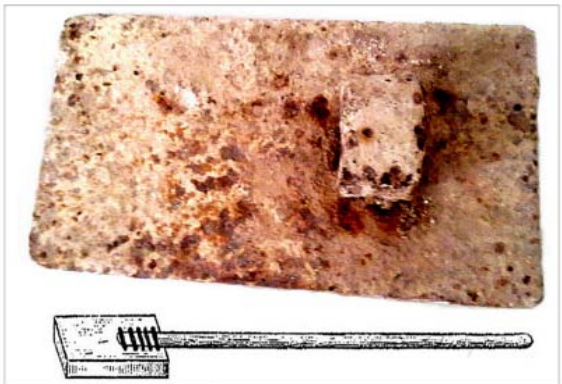


2.2. Concentration: crushing, picking and washing.



Simple stone-lined circle.
J A Soler Jódar

The first stage in concentration was crushing the ore to separate it from any unusable or unprofitable associated minerals. This was often done at the pit head to reduce the cost of transporting the material to the foundries. Crushing was frequently a manual process, particularly at the smaller concessions. The rock was placed into a stone lined circle and hit with heavy wrought iron sledge hammers which had relatively flexible handles.



Sledgehammer & handle fixing.
J A Soler Jódar

Crushing circle in the Barranco Jaroso.

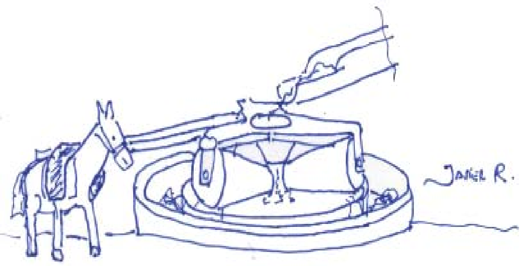
Hammering the rock has reduced it to pea-size lumps.

Another method sometimes used at the larger mines was the animal powered crusher like the one shown below. This worked by repeatedly rolling a cylindrical stone over the ore in order to crush it.

Simple mule-powered crusher.

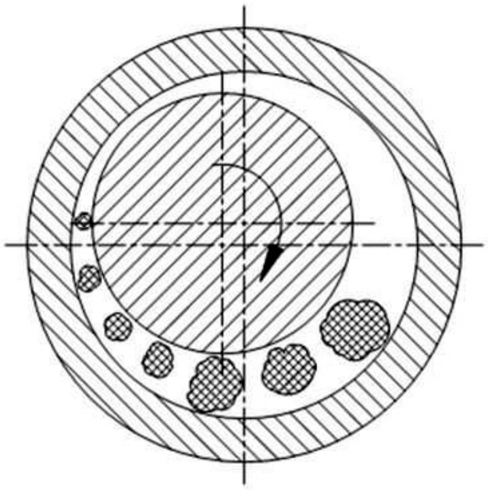
Cylindrical stones of the type used in these mills. *A G Jódar*

An advance on this device was the use of two cones as shown below being operated by a three-legged mule! These mills were the same type as those used in olive oil production. The efficiency of the action of the two cones on the particles can be seen in the diagram of a modern cone mill.



The three-legged mule. *Javier Rodriguez.*

Cones from an olive mill. *Antigüedades Diego Reinaldos.*



Action of the cones in a modern cone mill.
Intech GmbH Downloads

The fine grain gangue around the mine La Iberia is possibly due to the use of a cone mill.

Unless any of the mines harnessed steam power, or later electricity, I don't think that any truly mechanised methods of grinding or crushing were used at the pit head. Water powered stamp mills were not an option but steam power could have been used. The electrical power supply to the Sierra – when it finally came – would not have been sufficient to drive devices such as ball mills.

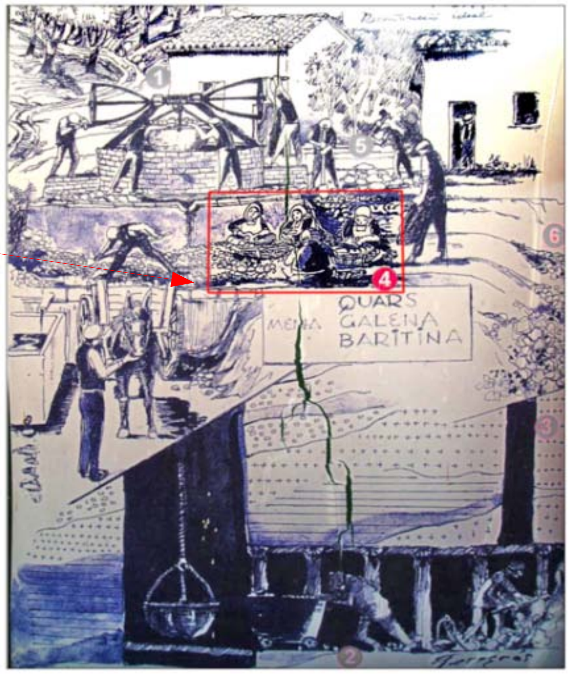
After the initial crushing the material was sorted.

The profitable ore or "mena" was sorted into various well defined grades. This classification seems to have been the same throughout the various mines. I suspect that there was a generally accepted assay standard for each type. "Recio" described larger pieces of galena with the smallest quantity of gangue. "Garbillo de primera" was fine ore in which only a low proportion of barite and other non metallic substances were present. "Garbillo de secondo" were minerals in which argentiferous elements were found in a low proportion relative to the gangue. Low quality ore was called "guardillón" or, ore leftovers. Each grade commanded a different price.

The patio de minerales of a mine in the Sierra circa 1874
Rodrigo.

In many parts of Spain this picking was done by women just as it was in Cornwall by the "bal maidens" who worked at the tin mines. However, in the Sierra Almagrera this was not the case. Contemporary accounts in the 1840s speak of a wave of cat-calling and a cacophony of tool banging if a women were even to set foot in the Barranco Jaroso. This may have been due in some part to the fact that the workforce travelled a long way to the mines and did not return home for extended periods. The women stayed at home and worked the land. However, by the 1850s women were occasionally found in the canteens of the larger mines. This absence of women may explain the higher than usual numbers of children employed in the area.

*This wonderful drawing by Joan Ferrerós shows a pit head in Montrás, Girona. The women (**4**) can be seen picking the ore. Behind them are the men crushing it with hammers in a stone circle. It is graded in the settlement tanks on the left and then loaded into the mule cart.*



Following crushing and picking the ore was then washed to remove any loose organic material. Occasionally, this was done at the pit head in the “porches de limpia”, and there is also evidence of ore washing in the bed of the Jaroso, below the artificial water channel. The site used water that was channelled down the Jaroso Valley as well as the water pumped up from the nearby de-watering plant.

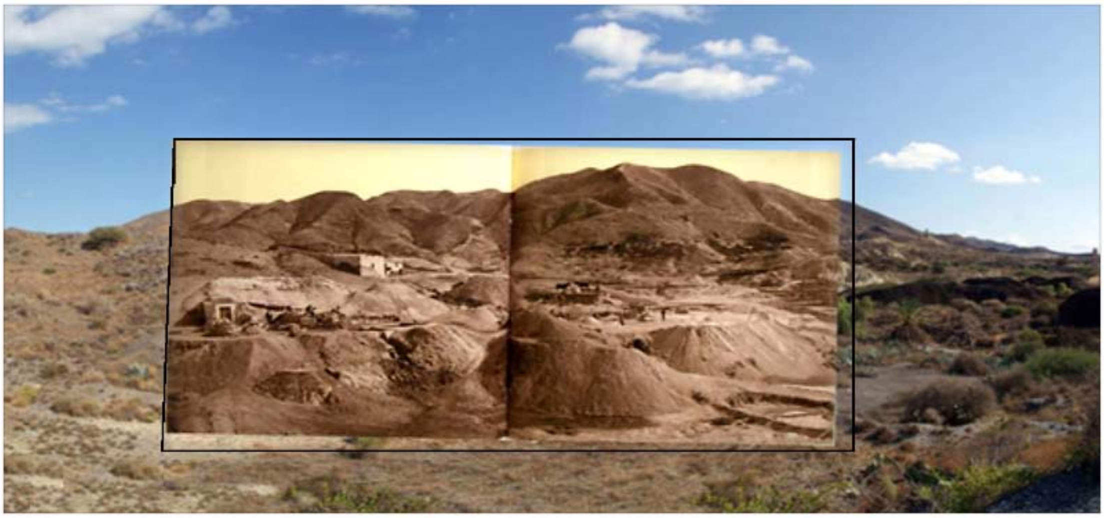
The probable remains of ore chutes in the Jaroso Valley.

The planking is probably the remains of ore chutes, directing the ore into mills or rumbos. There is a marked similarity between images above and those found in A G Jódar’s ‘Bajo Los Esparales’ post about the Sierra Almagro. On the next page the picture on the left shows an almost intact chute while that on the right, taken 30 years later, shows what time and erosion can do.

Ore chute in the Sierra Almagro – then & now.

Helios & Jódar

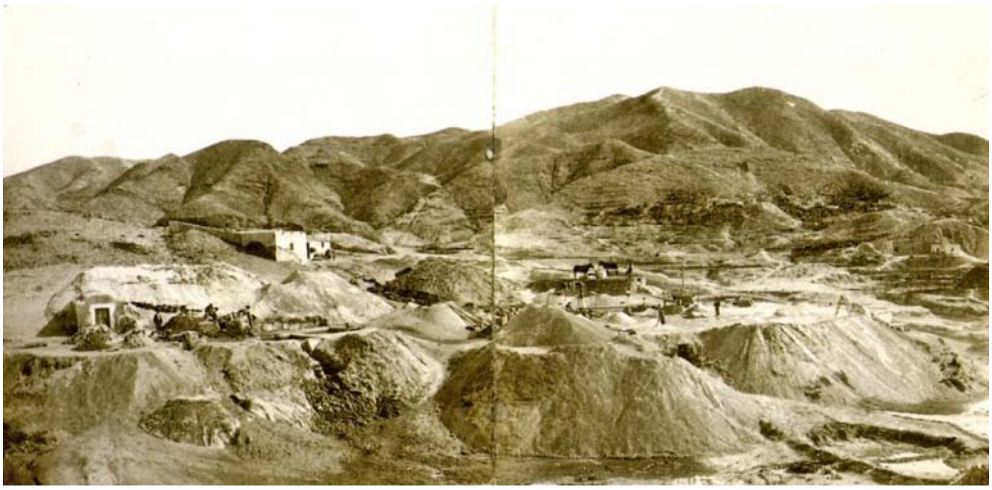
More often though, washing was carried out at dedicated lavaderos, or washing plants, like the one shown below



The washing plant, or lavadero, at El Tomillar.

Photo montage A G Jódar using the original shown below by José Rodrigo.

With the adjacent Rambla de Muleria in full spate and water cascading down onto it from the Barranco de Chaparral, this lavadero was badly affected by heavy rain in November 1879. A young child who was playing in the area a few days later died when an underground fume tunnel, affected by the softening of the ground, collapsed.

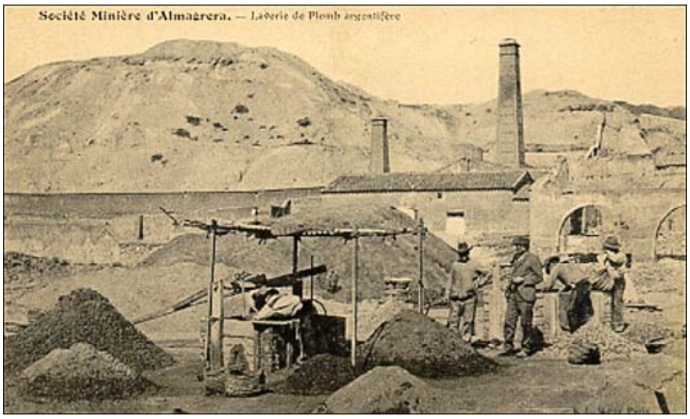


The scene today. Only mounds of fine waste cover the entire area.

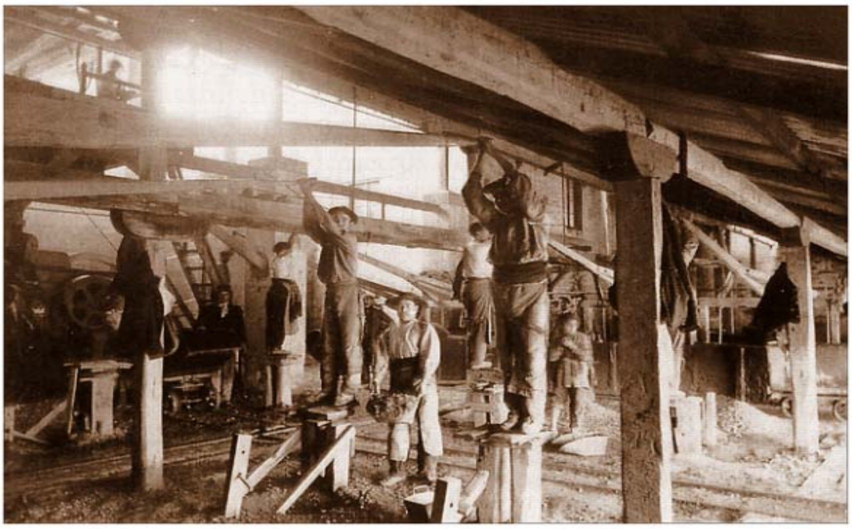
Another lavadero was situated below what is now the football pitch in Los Lobos. The remains of a rumbo were revealed after the catastrophic flooding in 2012. It is highly likely that it had been destroyed by previous flooding of the Rambla de Muleria. Lavaderos, because of their need for a water supply, were vulnerable to inundation and destruction whenever the heavens opened unleashing the powerful “gota fria”.

The most basic washing method was jigging in a “criba cartegenera” where soil and other debris was literally “sloshed” over the sides of a bath. The crushed ore was spread over a screen that formed the base of a box. This was then lowered into a larger box full of water. The screen was jerked up and down by means of attached hand- operated levers. This sharp jerking motion forced water up through the screen or sieve. The ore was held in suspension while the debris was carried over the sides of the screen's box into the gap between the two boxes by the water.

The inner screen of the criba cartegenera.
regmurcia.com



A criba cartegenera in use at a mine in Las Herrerías.
E.L.Morin.



A criba cartegenera in use at a lavadero in Jaén. The pedestals and the long levers counteracted the sheer weight of the lead.
T Céron.

Another common method of ore washing, particularly the smaller lumps, was a "rumbo" or round buddle as they were called in England. This was a circular pit made of masonry in which the floor sloped down towards the outer edge. The crushed ore, mixed with water to form a slurry, was fed into the middle. Tarpaulins or vanes suspended from beams fixed to a central, powered shaft, brushed against the slurry mix.

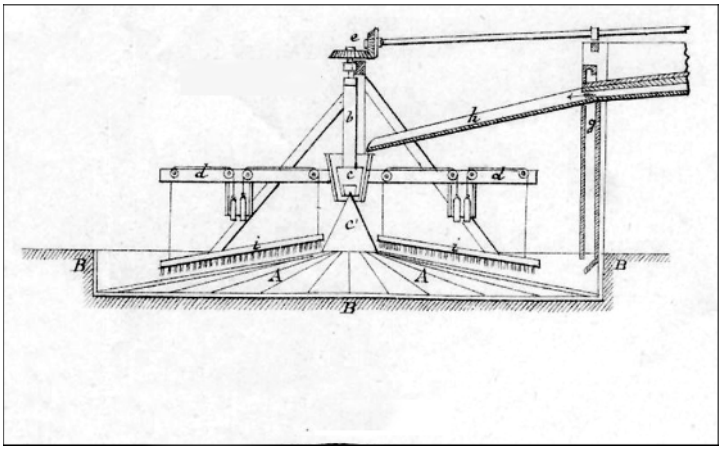


Diagram of a rumbo or round buddle.
G Moncada

As the shaft rotated, the heavier mineral remained near the centre. Less dense ore moved further out, and the lighter, unwanted material, or gangue, moved towards the edges from where it was removed and the liquid drained. The remaining bands of different grade ore were extracted in a concentric pattern using special flat shovels.

The remains of a rumbo shovel
farodededar.com

The beauty of the buddle was that it was cheap to construct and required little motive power. It could be operated by hand, often by children known as "cigüeña" or "storks", by animal traction or, if available, water power.

Two views of the buddle below the mine San Edmundo in the Barranco Jaroso

The ore was mixed with water in this area (above) and fed into the buddle via the simple pipe line made from roofing tiles (right).

Detail of a rumbo showing the feed line.

regmurcia.com

2.3. Roasting.

The concentrated ore was prepared for smelting by roasting or calcination, heating in the absence of air to a temperature below that of fusion, This destroyed any remaining organic matter, drove out moisture and made the ore porous. The lavadero below San Edmundo in the Jarosso valley had a very primitive calcining oven, the remains of which can be seen in the photographs. Originally it would have had a chimney similar to that shown below, right. Judging by the amount of calcined waste to be found in the Sierra, particularly in the Jarosso Valley, I'm sure that many other mines roasted their ore. The problem is that the ovens were so simple that little trace of them remains.

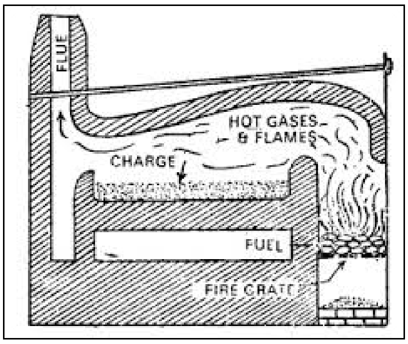
Above and right, primitive calcining ovens. *Above photo. J A Soler Jódar*

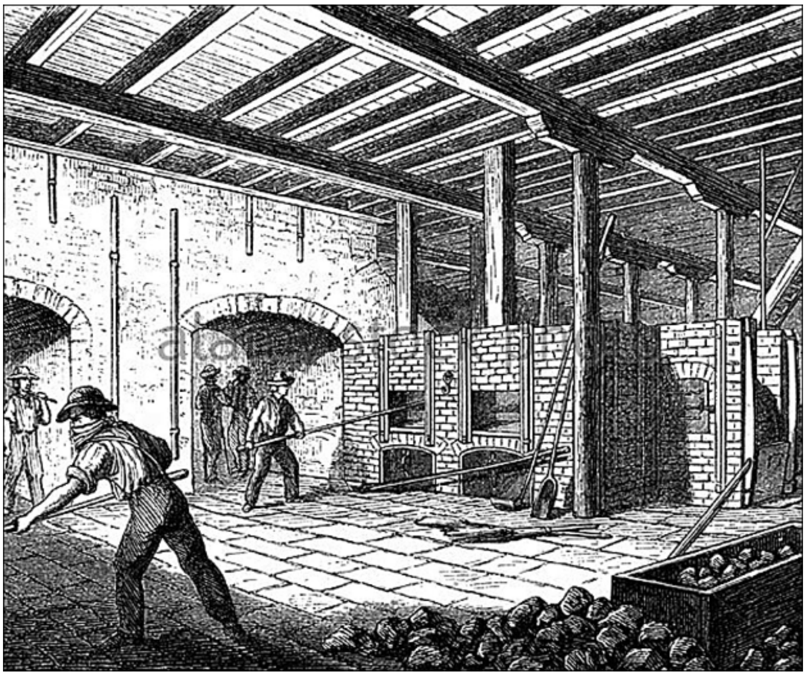
Originally, ore was roasted in brick-built stalls, about one metre high, arranged to form prismatic spaces within a quadrangle. The ore was arranged on a bed of pine wood which was then lit. When the temperature became high enough to burn some of the sulphur, this combustion was sufficient to maintain the heat required for the process. After about 12 days the fire went out of its own accord. The ore was sufficiently dried and purged to be smelted. No provision was made for capturing the toxic fumes that were given off.

Roasting ore in the open air.

Later, as concentrating methods improved and the supply of pine wood was dwindling, the ore was calcined in reverberatory furnaces at a foundry. This was done by moving the material progressively closer to the fire and controlling the air supply.

By controlling the air supply to keep the temperature moderate the ore could be roasted.
chem-brains.blogspot.co.uk





Roasting ore in a reverberatory furnace.
Alamy stock photo.

At the moderate temperatures of the reverberatory furnace, the galena (2PbS) was partly oxidized to lead monoxide (2PbO) and Sulphur Dioxide (SO_2).

$$2PbS+3O_2 \rightarrow 3PbO+2SO_2$$

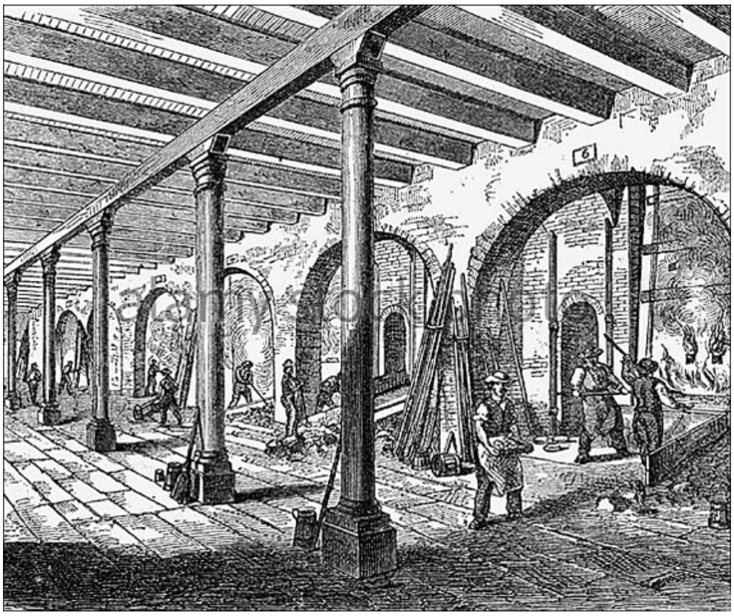
and partly to lead sulphate ($PbSO_4$) and sulphur dioxide (SO_2).

$$PbS+2O_2 \rightarrow 2PbSO_4$$

The addition of lime to the ore in the calcination oven reduced the amount of toxic sulphur dioxide.

2.4. Smelting.

Although smelting could be achieved in the same reverberatory furnace as roasting, for some reason, in this part of Spain, it was done in a blast furnace known as an ore-hearth.



Blast furnace or ore hearth.
Alamy stock photo.

By adding more galena, reducing the air supply, and raising the temperature the lead sulphide reacted with the two oxidized products giving lead (Pb) and more sulphur dioxide.

$$PbS+2PbO \rightarrow 3Pb+SO_2 \quad \text{and}$$

$$PbS+PbSO_4 \rightarrow 2Pb+2SO_2$$

Smelting produces impure lead, known as lead bullion. It also produces regulus or matte, consisting of sulphide of iron, sulphides of copper and other metals. This floats to the top of the lead when it is tapped. It is brittle when cold and can easily be separated. In addition, grey slag is produced. This is mainly silicate of iron, but generally contains sufficient lead to warrant re-treatment to recover it.

2.5. Liquation and desilverisation

One of the impurities contained in the lead bullion was the all important silver. Further heating was necessary to refine the lead and separate out the silver using the process known as cupellation. Cupellation works on the principle that precious metals, unlike base metals, do not oxidise, when they are heated at high temperatures. The impure lead was heated to 960 degrees C. in a furnace lined with porous, lime-rich material, and air blown across the surface. This oxidised the lead to lithage, (lead oxide, PbO) which was separated from the liquid silver. This process was carried out in a reverberatory furnace.

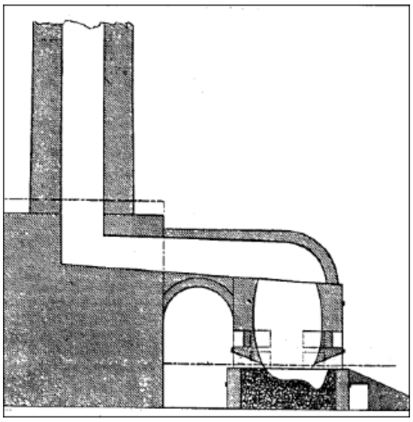
$$Ag+2Pb+O_2 \rightarrow 2PbO+Ag \text{ (liquid)}$$

The lithage then needed reducing back to lead.

Cupellation of silver into 'cakes'
Alamy stock photo.

2.6. Scavenging.

The regulus and grey slag resulting from smelting, together with the lithage, was scavenged to extract any lead present. This was done in a blast furnace known as a slag hearth. The lead obtained was known as slag lead, which was hard, due to the presence of sulphur, copper and iron. A commonly used slag hearth was a horno Cartagena, which was developed for the reprocessing of slag. This was an unusual, hybrid furnace where there was no artificial blast of air. The required draught through the tuyères, or blast pipes, was actioned by an arched chimney. It was classed as a blast furnace because the ore and fuel were mixed.



The Spanish slag hearth with its arched chimney providing the "blast".
Percy

2.7. Purification.
The hard, slag-lead was then purified, or softened, in a reverberatory furnace. The impurities were oxidized and collected on the top as dross. The dross was a dull brown colour and was hard and heavy. Mountains of it can be seen by the ovens of the Nueva Foundry on the coast road to San Juan.

Dross from the Nueva Foundry. The San Juan road is behind the 'crenellated' walls.

2.8. Foundries
Hot on the heels of the discovery of argentiferous galena, the Spanish Government passed a law, in 1840, prohibiting the export of the unrefined ore. Ostensibly, the reason behind this was to promote the growth of indigenous expertise. However, the increased revenue raised by taxing silver bullion was widely believed to be the reason behind the move.

As a result of this law there was an explosion of both small and large foundries, known as "boliches" and "fundiciónes" respectively, along the coast and at the foot of the Sierra. The initial problem with complying with the new law was, naturally enough, lack of expertise. While smelting galena is a relatively simple process, producing good quality lead, through the correct control of the sulphides present, is not.

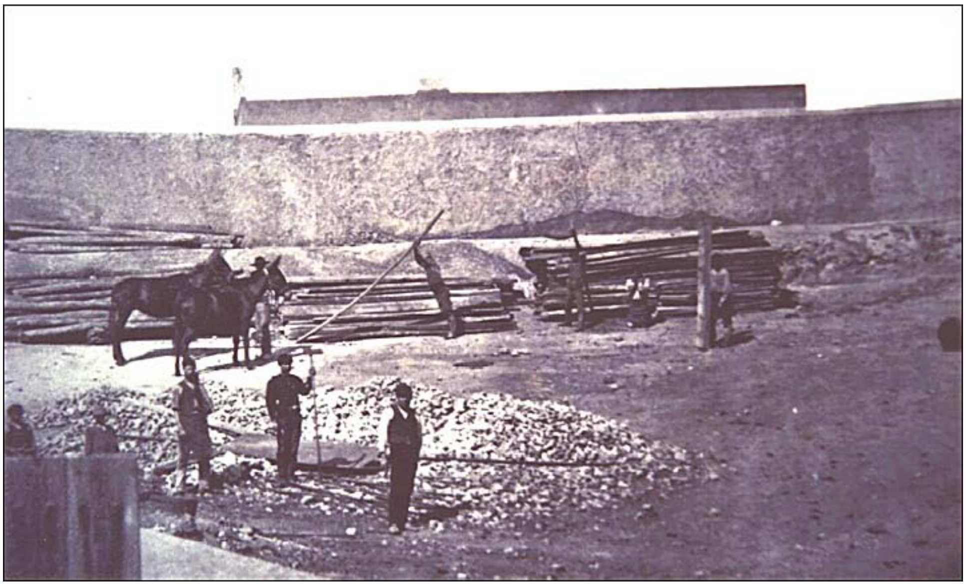
This foundry at Las Rozas was known as El Boliche even though its name was La Araucana. The term boliche also referred to the fact that it used Spanish reverberatory furnaces. These had no fire grille since they used wood for fuel.

El Boliche.

El Boliche or La Araucana as it is today in Las Rozas

The wood for the Spanish furnaces can be seen in this photo.

Rodrigo



The owner of La Araucana also built the Fundición San Francisco Javier in Palomares. This was much larger, and occupied the whole of the lower part of Palomares below the remains of the chimney.

The entrance to the San Francisco Javier.

Rodrigo

The approximate area covered by the San Francisco Javier foundry.

Another problem was the lack of infrastructure, in particular transport. The ore was taken in esparto baskets on the backs of mules and donkeys to even the largest foundries.

The esparto panniers can be seen in this photograph of the San Jacinto foundry at Las Marinas-Bolago near Pueblo Laguna. *Rodrigo.*

Then there was the reluctance, on behalf of the owners, to make any capital investment. A classic example of this was the heating of the smelting furnaces. To achieve the necessary temperatures for the process either bellows or fans were needed. Fans were operated by 3 teams of horses or mules working 8 hour shifts. Bellows were operated by men, known as palanqueros from “palan” meaning lever, who worked 4, six hour shifts. It was cheaper to operate bellows than to hire horses for fans.

Gradually, things improved and both men and horses were replaced by steam operated blasts. This was not without problems. The owners of the Contra Viento y Marea foundry at Los Lobos were taken to court because the wider spread of toxic fall-out from the chimney contaminated the pasture, killing the grazing animals. They were forced to move the chimney ½ a mile away. Soil contamination for this area remains a problem to this day.

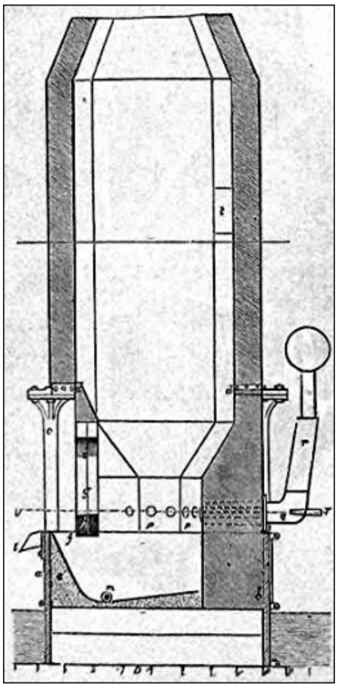
All that remains of the Contra Viento y Marea foundry. *mtiblog.*

The French Revolution of 1848 was a catastrophe for the Almagrera. 90% of the silver produced had, until then, been exported to France through the port of Marseilles. It was a classic case of all the eggs in one basket. Profits at the foundries plummeted, as in turn did those of the mines. The government stepped in and authorised the banks to buy silver on behalf of the treasury. However, there was a sting in the tail to this move. Producers of silver were taxed, paying 5% on total production as if it were all of high quality even though, by this time, the majority was of a lower grade.

Soon, the industry was in deep trouble. They were having to mine deeper for lower grades of ore. The higher amounts of impurities were making smelting more costly, since it required a greater amount of imported English coal. Some foundries shut down their furnaces, waiting for an upturn in fortunes.

In 1850, the law was relaxed and tariffs were imposed on imported galena. Some foundries resumed production of unrefined ore to be shipped to England for processing. Only the San Jacinto foundry at Las Marinas-Bolago near Pueblo Laguna made any real capital investment in terms of upgrading their furnaces. They introduced the Piltz blast furnace which had the water cooled jacket that is still a feature of modern blast furnaces. They also used the hot water generated by the process to drive the air blast.

Diagram of a Piltz furnace.
The Engineer, July 1874



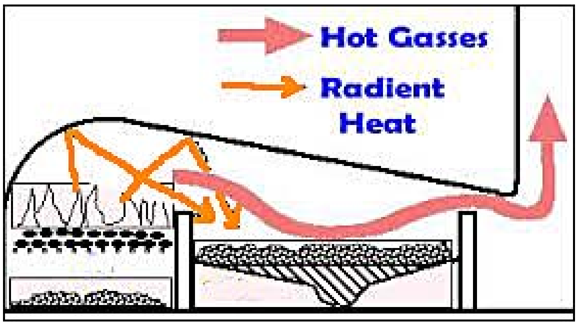
1870 saw a general fall in lead prices. Silver was fluctuating on the international market and many countries were moving away from using it in favour of gold for their currencies. The days of the lead foundries were numbered and one by one they closed.

2.9. Furnaces.

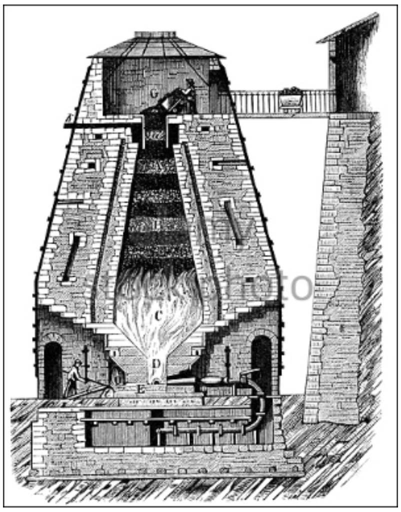
A variety of furnace types were used in the foundries that sprung up in the area.
A contemporary account by Madoz (in his Geographical Dictionary of 1845) of the Madrileña or Duro foundry, which was situated behind the pine wood between the Repsol garage and the mouth of the Almanzora, lists the following.
5 hornos de manga.
3 hornos reverberos.
2 hornos de copela inglesa.
2 hornos de copela de alemana.
16 hornos de calcinacion por el systema inglés.
3 pilas grandes por el aleman.
1 horno para la calcinacion de huesos.

That is quite a battery! Researching the subject was difficult because many of the types also went under different names, but I think that I have sorted it out.

Furnaces fall into two main categories, reverberatory and ore hearth. The main difference between the two is that, in the former, the fuel and ore are kept separate, the heat reverberates in the hearth chamber, while in the latter, they are mixed, and an artificial blast of air is required for efficient operation. The term blast furnace refers to this artificial blast of air.

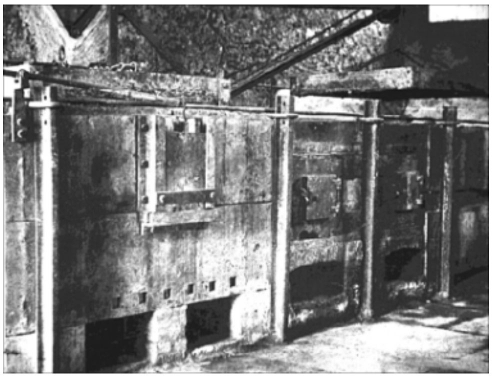


Section of an English reverberatory furnace.



Section of an early blast furnace.
www.alamy.com

The 16 hornos de calcinacion por el systema inglés would have been reverberatory furnaces of the Flintshire type. These were generally arranged in a row, often in an arcade which served as support for the common flue. I don't know why the smelting wasn't done in the same furnaces, as was the case in England.



Hornos de la fundición This bank of furnaces in the foundry that was at Las Marinas-Bolago, has an English cupellation furnace (left of photo) and Flintshire furnaces on the right.
Rodrigo

The 5 hornos de manga would have been ore hearths. The term manga refers to the fact that that the air blast was generated by sleeves (arms), in other words, hand operated bellows. These were most likely hornos castellanos. These were unusual in that they had 3 tuyères, or blast pipes, rather than 2, possibly because they were hand operated. These furnaces could be operated in tandem, as shown in the illustration, making good use of the motive force.

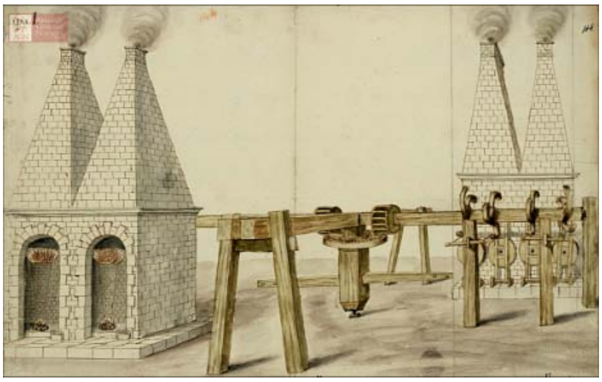
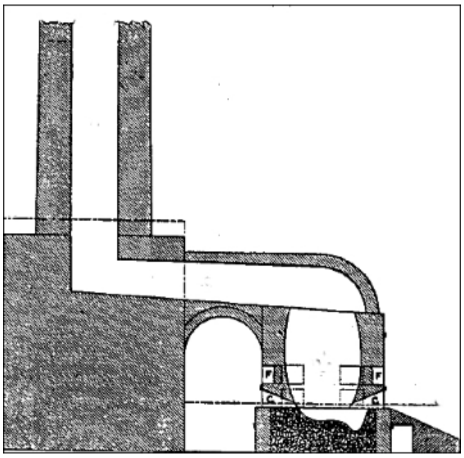


Diagram showing hornos castellanos being worked in tandem.

Remains of two hornos castellanos in Alcora.
I Jiménez Terrón.

As the writer doesn't mention any horno Cartegena, it seems that the Castillian furnace was used at this foundry for both the ore-hearth and slag-hearth stages. This is strange, given that the motive force at this foundry was man-power. The Cartegena furnace needed no bellows for its operation.

Horno cartegena.
Percy.



The 2 hornos de copela inglesa and the 2 alemana were English and German cupellation furnaces. Why they would want to use both types is another mystery. Cupellation furnaces were reverberatory furnaces, unusual in that they had a forced air supply. The design of the two types differ considerably, but the results were pretty much the same.

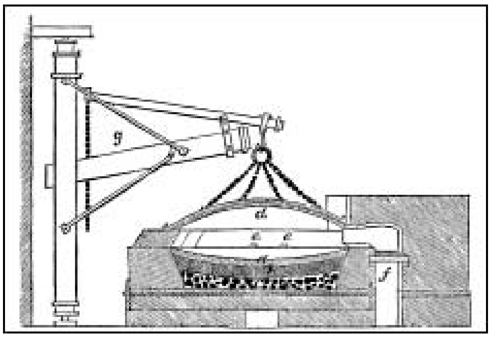
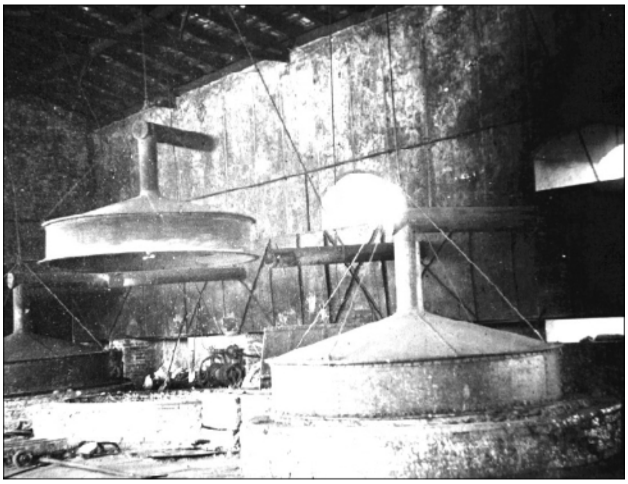
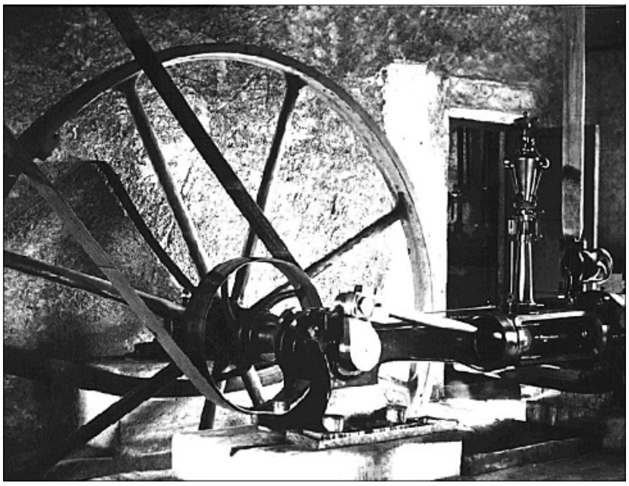
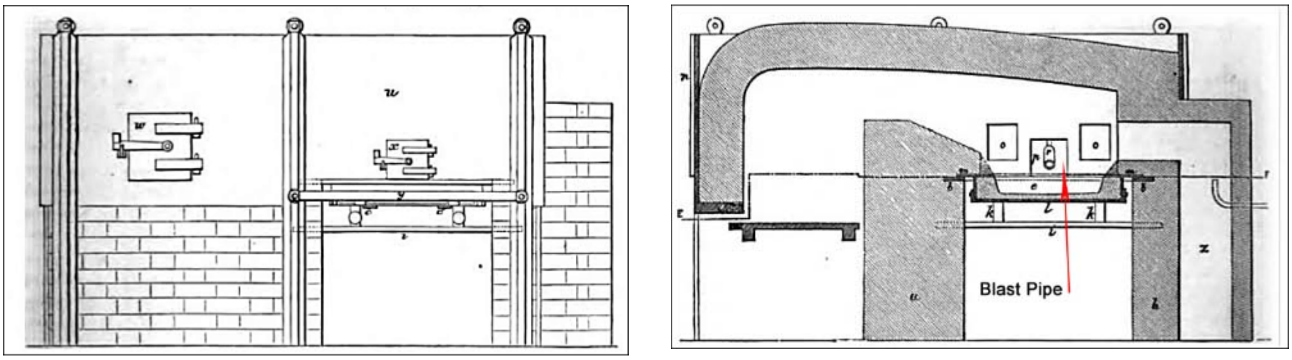


Diagram of a German cupellation furnace.
The domed lid was lifted by a crane.





These German cupellation furnaces and the steam engine (right) that provided the blast of air were in the La Española foundry in Garrucha. *Rodrigo*



English cupellation furnace: exterior and interior.

The 3 hornos reverberos would have been the Spanish reverberatory furnaces. These differed from the English style in that they had a second chamber. These would probably be used for purifying the hard slag-lead. While originally constructed to burn wood, many of these Spanish reverberatory furnaces were modified to burn coal by the installation of a fire grate.

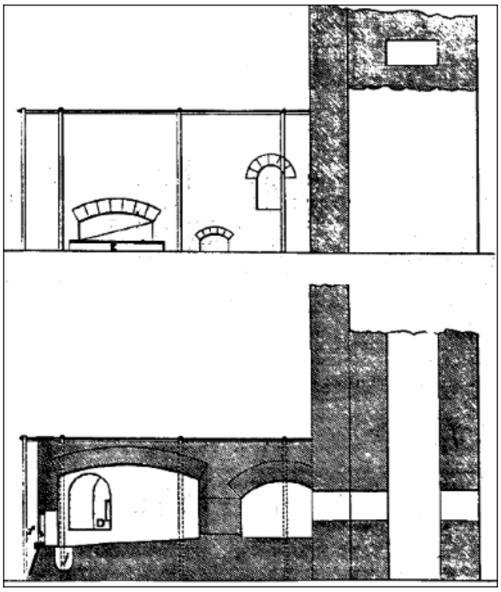


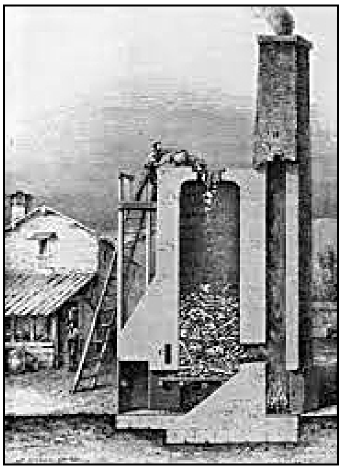
Diagram of a Spanish reverberatory furnace. *Percy.*

The 3 pilas grandes por el aleman would have been coking ovens, converting the British coal to coke, providing the fuel for this enormous battery of furnaces.

Coking ovens. *A Cabrera.*

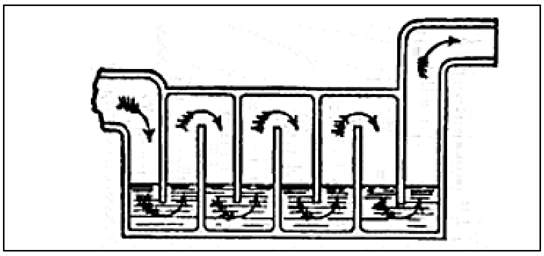
Last, but not least, 1 horno para la calcinacion de huesos. A bone calcining oven, the bone ash was used to line the English cupellation furnace where it absorbed a considerable amount of the lithage.

Bone calcining oven.



This foundry was unusual in that it didn't use the snaking condensation tunnels that are such a feature of the coast line. Instead, it used a Stokoe twin condensation chamber to which all of the furnaces would have been linked. The fume was forced through the off-set bank of stalls, while a mist of sea water descended from a reservoir at the top of the chamber. Brushwood, laid on an arrangement of horizontal beams, filtered the fume as it passed from one water trough to the next. When the water reached a certain level it was run off and the sediment in it collected.

A Stokoe condensation chamber



Not a single trace of any of this remains, apart from a small amount of black slag.

In the summer of 2016, this edifice appeared on the roundabout on the coast road below Palomares. I assumed that it was a representation of a furnace, but with too much artistic license to say which particular type it is meant to be.

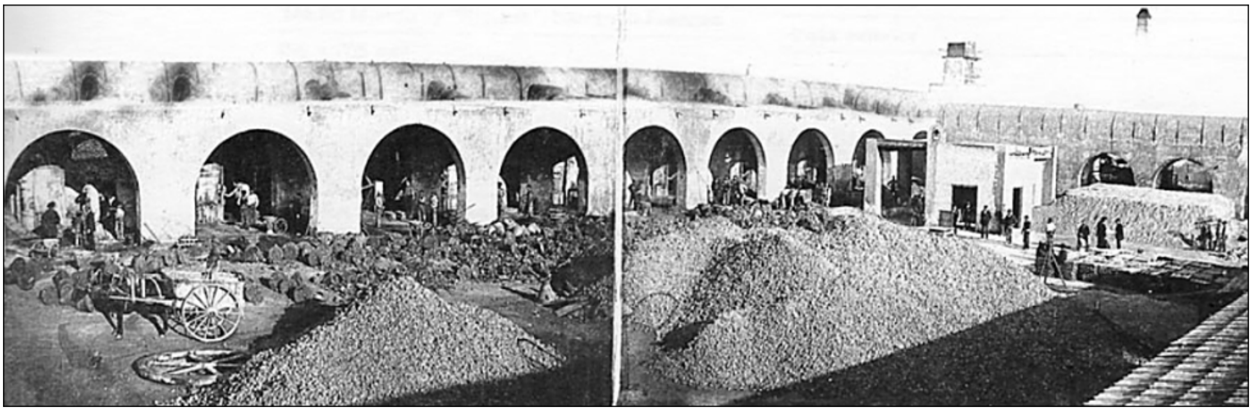
I was pleased to see this acknowledgement of the area's history positioned as it was equidistant from three foundries, the Madrileña, the San Francisco Javier and the Don Guillermo.

I have since discovered that it actually represents part of a castle, the Castillo de Marques de los Velez, in Cuevas del Almanzora! Señor Jódar could understand my assumption but gently corrected me.

Cuevas castle. The arch is tucked away in an obscure corner of the inner courtyard. *elalmanzora.com*

2.10. What's left?

So what is left to be seen today? A ride along the coast from Villaricos to Pozo del Esparto gives a glimpse of the past. The arcade of the Invencible foundry is unmissable. All that remains of the battery of furnaces are these arches which supported the fume flues. They would have been similar to these arches and fume flues at the San Jacinto foundry at Las Marinas-Bolago.



Galeria de hornos at San Jacinto. *Rodrigo.*

When the coast road was constructed, drainage water was channelled onto the site and only the air intake tunnel and a few bits of masonry from the back of the ovens has escaped erosion.

Remains of the arches of the Invencible foundry. All that is left of the furnaces can be seen at the base of the arches.

The draught of air for the furnaces entered by this opening, which can be seen from the road.
mtiblog.

When I first saw these arches, I thought that they were for carrying the noxious gases out to sea. Only later did I realise that the lead fume was carried in the other direction and passed through the kilometres of snaking tunnels that wind round the hills.

These condensation tunnels can be seen on the left shortly after passing the arches. *Photo. mtiblog*

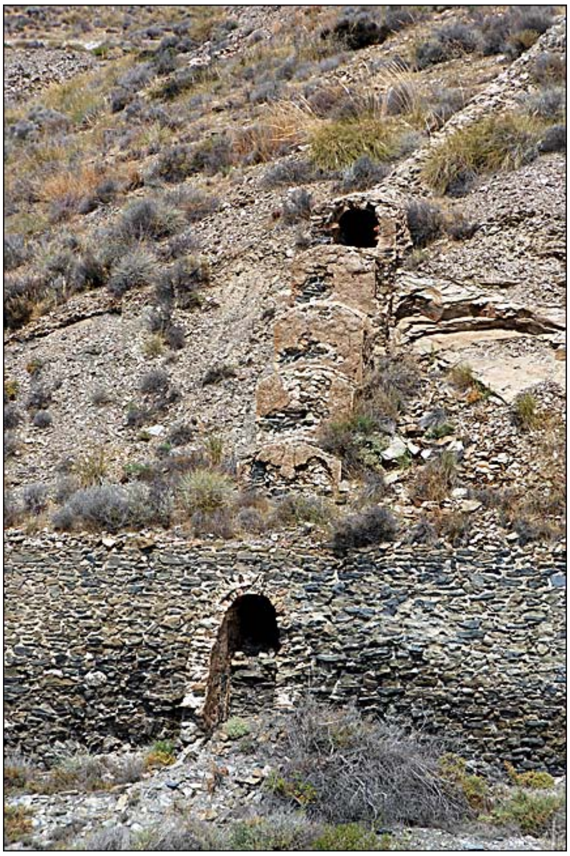
As well as sulphur dioxide, the fume from the various processes contained a certain amount of lead. As the fume passed through the tunnels it cooled and the lead content precipitated, caking on the sides. About once a year, men and boys entered the tunnels through the shuttered access points and recovered the lead by scraping it off the walls. This was then processed along with any grey-slag and lithage.

Inside the tunnel (left)
and an entrance door (above).

The men and boys who went in were equipped with a handkerchief to cover their mouths and noses and were allowed a day off to purge their systems. Small wonder that the life expectancy was so low!

Just a little further along the road are the remains of the Fábrica Nueva. This foundry was more substantial than the Invencible and it was powered by steam engines. The fume flue was carried along the top of the furnaces, then across to the labyrinth of tunnels.

The furnaces seen from above and from flue level.



The fume flue at the start of the serpentine.

The openings through which the ore was introduced, or charged, can be seen from the road and are uniform in size and position.

The furnaces were charged from this side.

However, on the lower, seaward level where the ore was worked, the openings are different, indicating two distinct types of furnace.

The lower working level.

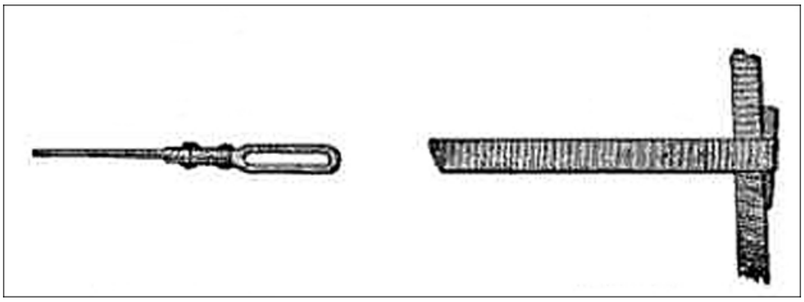
The other type furnace opening.

The first eight furnaces are reverberatory calcining ovens and the last few are possibly blast furnaces indicated by the different type of opening (above). The whole structure has been filled in and the openings stoppered.

When I saw this iron eye hook embedded in the wall by one of the working doors, I thought that it was a rabbling tool and got quite excited about it, imagining someone using it to rake the ore through the calcining oven a hundred years ago.

Iron eye hook.

On a second visit to the site I found a series of them, at regular intervals round the oven. They were actually the fixing pegs of the furnace binders, iron bands that reinforced the structure.



Furnace binder and fixing peg

There is a noticeable difference between the slag at these two adjacent foundries. That at the Invencible is made up of small pieces, while that at the Fábrica Nueva has a lot of larger, red-orange, flat sided pieces as well as the more usual bubbled chunks. Maybe they used more iron as a flux, or, the ore was not cuppelated so the slag was not affected by the lithage.

Slag from the Invencible

Flat slag from the Nueva

Bubble slag also from the Nueva.

2.11. What's not associated with lead?

The oven at Quitapallejos Beach by the Repsol garage.

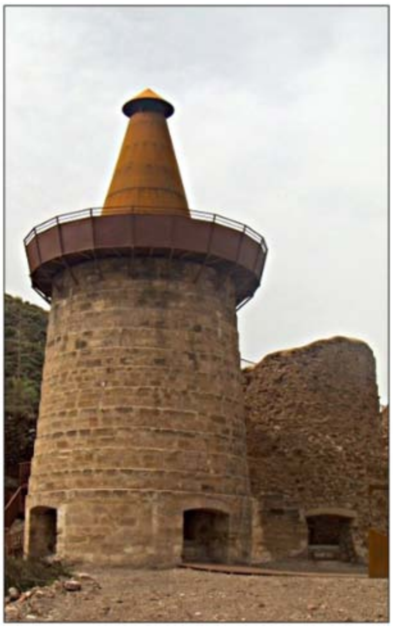
The ovens at Cala las Conchas.

There are several ovens in the area, like the ones shown above which were not used for the smelting of lead. This type of oven was used for the roasting of iron ore so was not covered in the section on furnaces for lead production.

They were simple roasting ovens used to burn off any organic material present with the ore, remove moisture, burn of any sulphur impurities and to oxidise Ferrous Oxide to Ferric Oxide. These ovens served the same purpose as the calcining ovens used for lead processing, the only difference being in the large quantity of air that was introduced to the process.

Ovens of this type had a metal tops and loading platforms as can be seen in these photographs of working and restored ones below.

Above, working ovens. (taken from La Minería del Hierro Contemporánea en Almería. Miguel Á Perceval Verde).



A restored oven.

There is an interesting oven at the mine Republica Romana with a cone inside that intrigued me.

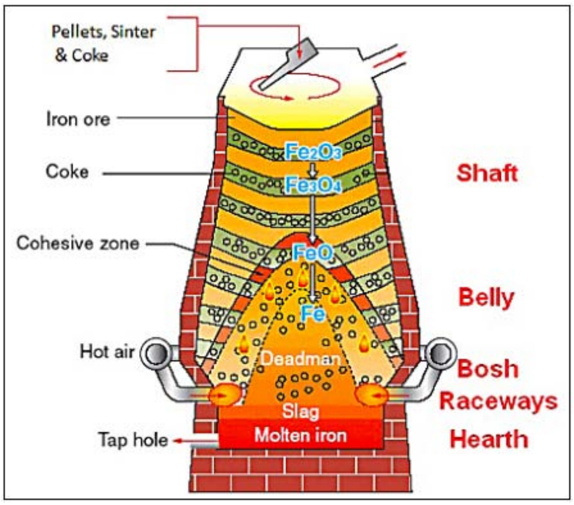
Republica Romana and the cone inside.

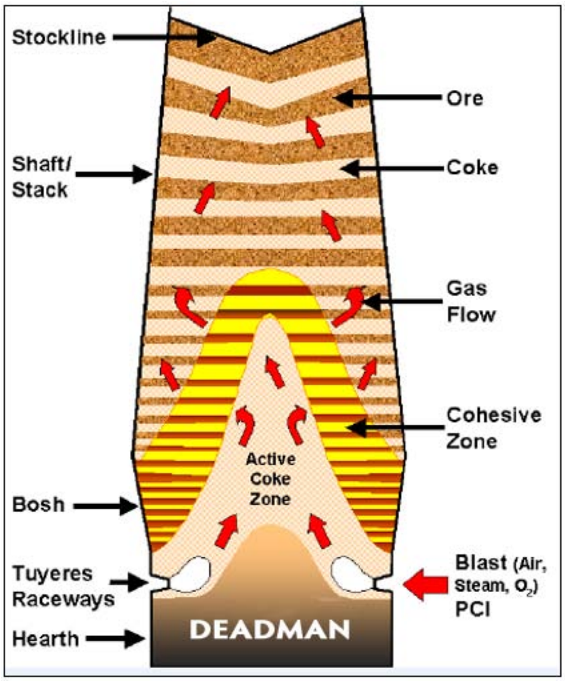
I have since found pictures of other examples of cones in ovens of this shape.

Left: Restored cone.

Right: Restored blast furnace door.

When I started to research the cones further, I found that they are known in Britain as the deadman. What I also found was that they are only found in blast furnaces, and play an important part in the smelting process. I can only conclude that the oven at Republica Romana is the remains of a blast furnace and that the ore was both roasted and smelted on site. This discovery solved one of my mysteries, I couldn't work out why there was so much unstable, bubbled slag around La Violeta and Republica Romana if the ore had only been roasted.





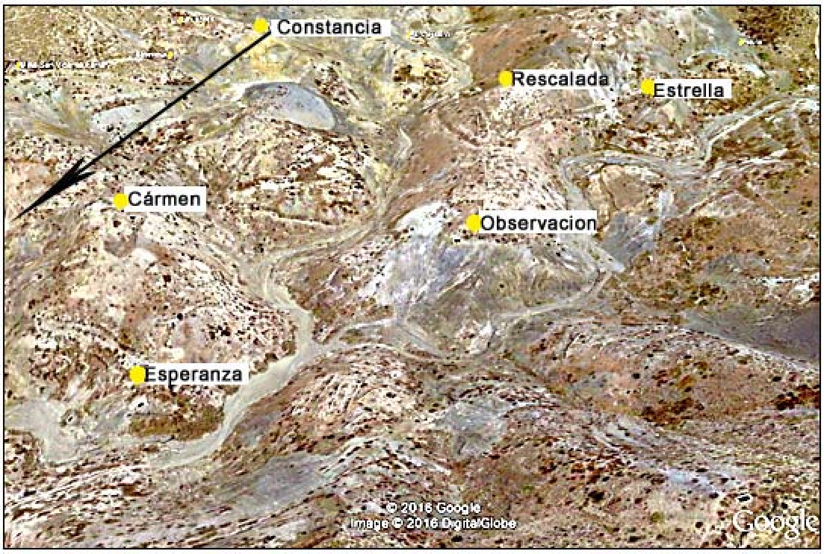
The above diagrams illustrate the importance of the deadman in assisting the conductivity of heat and the flow of the molten metal towards the tap hole.

Another mystery is this tower at the entrance to El Arteal. At first sight it looks like an iron roasting oven and is described as such on some websites. However, there are certain anomalies. Neither its size nor its shape conforms to the norm and, in addition, the number and position of its apertures would not have supported the calcining process. It looks more like a defunct water tower than an oven but, who knows? Perhaps, one day, I will have a definitive answer.

Chapter 3. Mine Development

3.1. In the beginning...
When the mining boom hit the Almagrera, the industry was governed by the 1825 Mining Act. The subsoil belonged to the crown, later to the state, and exploitation was allowed by means of concessions. The size of these concessions was strictly controlled, with the surface area of a demarcation limited to 200 x100 varas castellanas. (A vara is fractionally shorter than a yard at 32.909ins. or 0.9144m.) The majority of the early mines in the Sierra had a surface area of 13,974 sq. m.

The reason for the small size was an attempt to prevent wealth accumulating in too few peoples' hands. In practice, of course, it did nothing of the sort. Concessions cost money, 1,000 reales per annum, so who was likely to be able to afford one? Well, those already comfortably well-off, members of the clergy, landowners, merchants etc. Family connections played a big part. They were used to circumnavigate the restriction that any single person was only allowed to hold one concession. To get round this particular legislation, individuals would buy "acciones" or shares in multiple concessions which had been granted to consortia, consisting of various relatives or friends. They could also buy the services of a mining engineer to advise them on the likely position of the principle ore bearing seams. As a result the wealth of Cuevas del Almanzora was held in fewer than half a dozen families' hands. They were the ones who really struck gold, buying into the concessions that came to be known as "las minas ricas del Jaroso" (the rich mines of the Jaroso). Those of Ánimas, Constancia, Esperanza, Carmen, Observación, Rescatada and Estrella, all of which sat on the richest seam of galena in the whole Sierra.



The mines Constancía, Cármen, Observación, Rescatada and Estrella

The five richest mines Constancía, Cármen, Observación, Rescatada and Estrella. *Panorama, Rodrigo*

Share certificate for the Virgen Del Carmen mine.

Between 1839 and 1850, 70% of the production of the Almagrera was from these few mines giving their owners sufficient capital to invest in the canalization of the Rambla del Jaroso and some of its tributaries. Although the water no longer flows through this channel, its construction is to be marvelled at. Even right down at the entrance to the valley, its remains can still be seen. This is despite the torrents of water that cascade down after heavy rain. What it was constructed of I don’t know, but I wonder if it is a conglomerate containing slag. What ever it is, it has endured.

Section of the water channel in the upper Jaroso valley.

The section from Esperanza to Ánimas was mostly underground, in a stone-lined tunnel, which also took the water from a tributary.

The entrance (above) and exit (right) of the tunnel under Esperanza which channelled the rambla.

Now that the water follows its own course, so much of Constancia and Esperanza has been washed away. Every year the erosion gets worse.

The channel exit seen from above where it crosses the present course of the rambla. The tunnel exit is to the right of the photo.

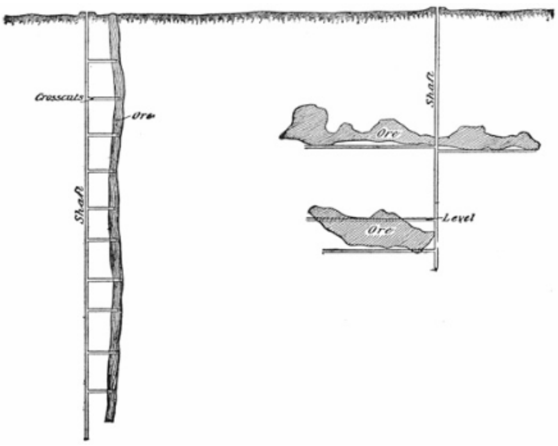
What of the rest of the concessions? Over 200 were granted. 1,700 shafts were sunk, 1,500 of these in the decade following the discovery of the argentiferous galena. However, official statistics show that in 1840 just three mines were productive, Observación, Carmen and Esperanza, and that by 1845, the number had only risen to nine.

What was happening was a great speculative movement, involving the buying and selling of shares in mines. This involved, not just people in the locality, but, as the tales of riches grew, people from Granada, Madrid and Barcelona were parted from their money. A second tier of moneyed gentry appeared in Cuevas and Vera, comprising of those who had profited from this activity. Many of these concessions were never even prospected never mind exploited. Even worse, many didn't even exist, so great was the extent of the fraud!

By the late 1840's, things had settled down. Everyone got down to the business of extracting the maximum amount of ore at the minimum possible cost. Mining is firstly about the search for ore and, secondly, the opening of avenues for its extraction. These two processes, the prospecting and the production, are difficult in hard-rock mining due to the nature of the ore deposits.

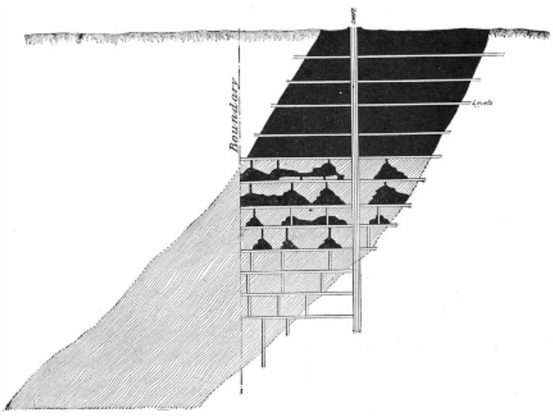
The principle method of prospecting in the lead mines of the Sierra Almagrera was to sink vertical shafts in the hope of locating a vein. If no vein was found, tunnels were bored out from the shafts into the county rock in an effort to find a lode. There are very few adits (tunnels from the slopes of the mountains into the mines for either prospecting or extraction) due to the restricted size of the concessions. As there was virtually no outcropping, or surface mining, of galena in the Sierra to indicate the presence and direction of a vein, the successful positioning of a prospecting shaft was very much a matter of luck. In the case of the principal Jaroso mines, where they were located pretty much at the centre of each concession, it seems that luck was on their side. Here, however, the lode was so wide and thick that it would have been difficult to miss. Many other mines waited for a neighbour to strike a vein and then prospected parallel to it in an effort to keep prospecting costs down.

Once a vein had been located a system of approach ways, or levels, had to be decided depending on its shape, size and inclination. Two simple methods are shown in the diagram below.



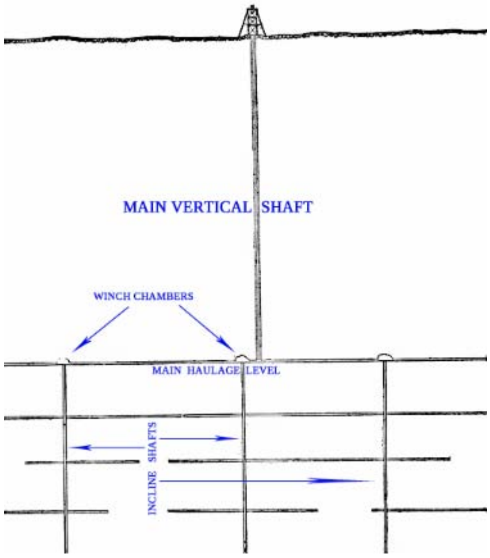
The approaches to vertical and horizontal ore veins.
Principles of Mining. Herbert C Hoover

There were further complications in the Sierra where, not only the dip of the lode and its position relative to the concession boundary had to be considered. The diagram below shows just how tempting following a wide seam could be.



The effect of concession boundaries on the exploitation of a vein.
Herbert C Hoover

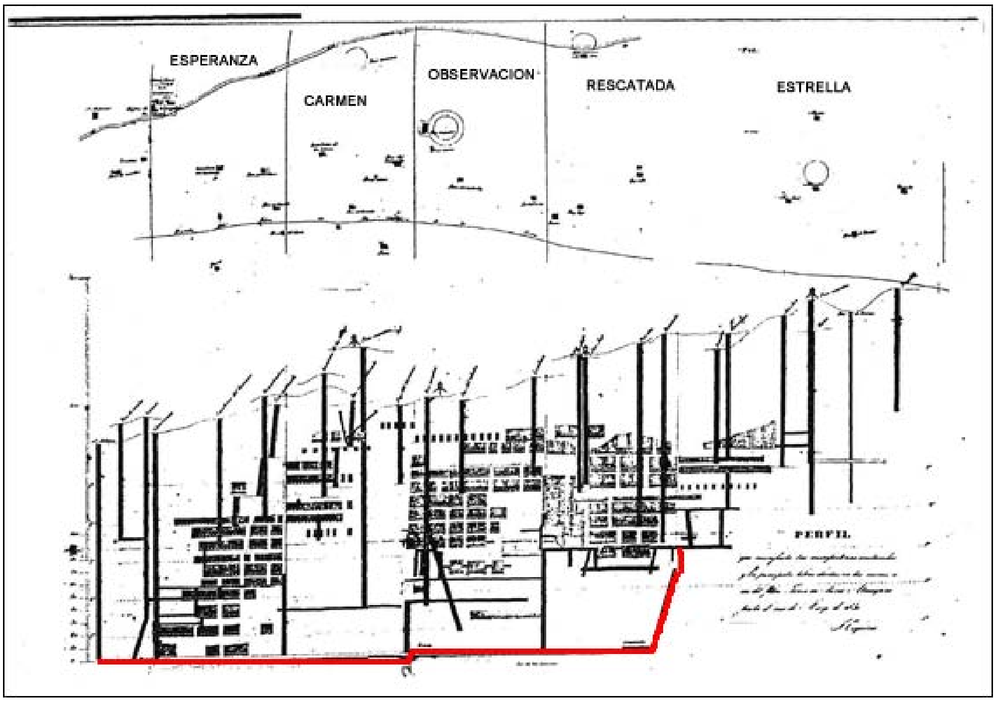
The diagram on the next page shows the optimum layout of a hard rock mine with the vertical shaft entering the top of the deposit. While the aim was to have an equal length of lateral tunnel in every direction from the shaft relative to the angle of the vein it was easier said than done. Ore shoots and veins are so unpredictable that this was rarely achieved.



The optimum layout of a lead mine, with a main shaft and levels.
Herbert C Hoover

Once the ore deposits had been located and assessed decisions could be made about secondary access and ventilation shafts and consideration given to the future development of the mine. This, at least, was the theory and was known as the 'art' of mining to which graduates of the School of Mines ascribed.

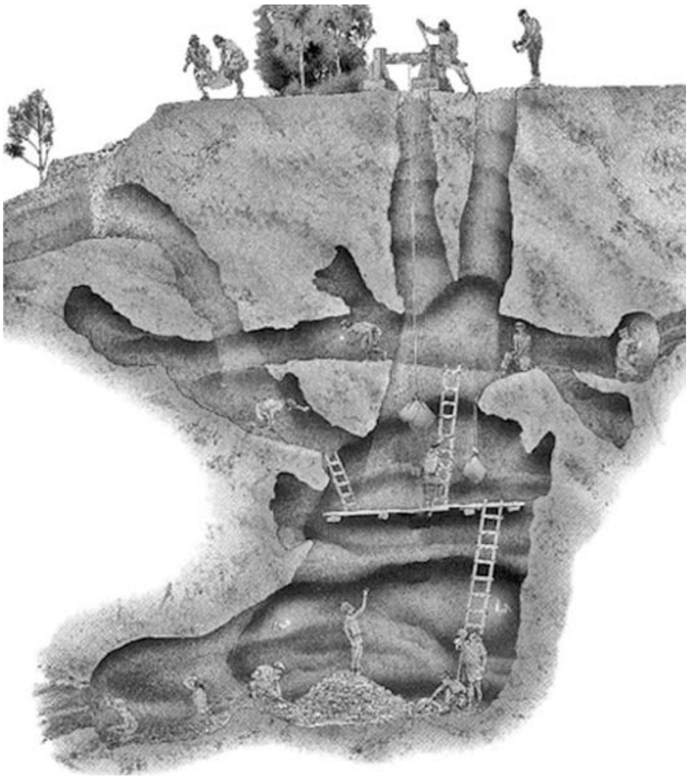
Ezquerra de Bayo's plan of the workings of the mines Esperanza, Carmen, Observación, Rescatada and Estrella, who employed qualified mining engineers, show well ordered workings. They also show a certain amount of co-operation, with inter-communication between the various levels of adjacent mines without encroachment on the areas of extraction. However, Bayo also pointed out that co-operation was not always the case between other mine owners.



Plan of the shafts and workings of the five mines showing how they were separate. The gallery that links them (shown in red) was for drainage and not for exploitation. In 1843, there were 1,650 underground workers in this 500 metre long section of the Barranco del Jaroso.

Plan by Joaquin del Bayo Ezquerra from La Mineria Almeriense en el Periodo Contemporaneo. (Perez)

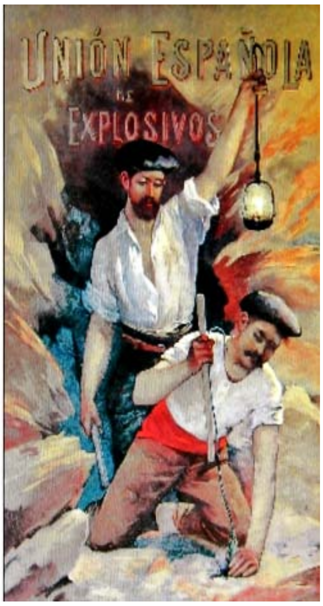
J. Pie y Allué, a mining engineer and director of the Vera School of Mining, was very scathing about many of the mines in the Sierra. Here, satisfying shareholders, getting rich quickly and maximising returns for minimal effort was the modus operandi. Such mines were worked with no planning or development. Veins were chased along their lengths without cross-cuts or haulage levels so they were a maze of narrow passages that rose and fell with the run of the mineral. This practice was very short-sighted as it meant that little or no prospecting was done. The illustration below of a medieval mine gives some idea of a mine worked without due thought to its development.



Poor planning in a medieval mine. Some of the mines in the Sierra were little better.

Openedition.org

A further major safety problem in many of the Sierra;s mines was the accumulation of waste rock. Mines in other parts of Europe generally had a fixed time – usually at the end of each shift – for the firing of explosive charges. Where there were firings during the shift the whole area would be evacuated. However, in many parts of Spain there was no fixed firing time and neither was there any evacuation as this interrupted production which lost money. Here, the barrenos, or shot-borers, set their charges at will and shouted "¡Barreno!" as loudly as they could. Their fellow workers would take up the call and all would hot-foot it to safety. Then, in order to save on cost, the resulting waste rock was left to accumulate in these narrow passageways instead of being either packed back into the stopes to prevent collapse or being winched to the surface. The dangers associated with this practice cannot be underestimated. Ezquerra de Bayo, whilst railing against the state of the passageways in even the most ordered of mines, attributed the fact that there weren't more deaths from this practice to the simple fact that the men were used to picking their way over the rubble. In his opinion it was recklessness and bravado that caused the most accidents. The English writer, Hugh James Rose, in his book "Untrodden Spain and Her Black Country", expressed the same opinion about the accidents during shot firing in the mines at Linares, attributing them to the same aspects of the Spanish temperament.



A somewhat stylized print of dos barrenos setting a charge

The 1849 Mining Act removed the royalist principle of land sovereignty, and eased the restrictions on ownership. The maximum size of a concession was raised to 300 x 200 varas. These later concessions in the area ranged from 40,000 to 50,000 square metres but existing concessions had to remain at their original size. Shafts had to be sunk in each concession and extending existing underground galleries into new concessions was not allowed. The conditions regarding the holding of a concession were complicated and many fell foul of them, leading to repossessions and redistributions. One curious condition was that a concession had to be in continuous operation, "pueble" or peopled by at least 5 operatives. Abandoned workings were the source of much litigation in the Sierra. Another problem associated with such a restricted surface area was the fact that a concession often ran against the grain of the mineral vein. This led to frequent intentional or unintentional incursions into a neighbour's dependency particularly if it had been abandoned.

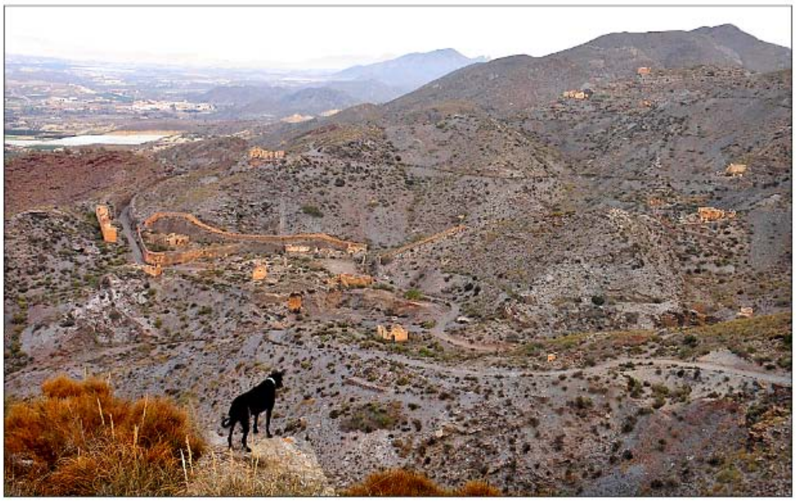
Legislation, in 1868, lifted the limits on surface area and removed the requirement to continuously operate a mine. More importantly, the restrictions on the number of concessions that an individual, or company, could exploit were abolished. This legislation was important because it opened the door to foreign investors who were not previously interested in operating on the small scale imposed by old, small concessions. While the so called "rich mines" of the Jaroso continued to be exploited by their owners, many others seized the opportunity to lease their mines. They ceded the working of their mines to prospecting companies in exchange for a percentage on the mineral produced. (This could be 40, 50 or even 60%.) By 1879, 60% of the mines in the Sierra were leased. The most important of the foreign companies at this time was the French company, La Compañia de Águilas.

3.2. La Compañía de Águilas.

La Compañía de Águilas marked a "before and after" in the history and development of mining in the Sierra Almagrera. Founded in 1881 in Paris, and with the might and money of the ubiquitous Rothschild empire behind it, the company soon became a dominant player. They expanded rapidly, not just in the Almagrera and Las Herrerías, but also Águilas, Mazarrón, Lomo de Bas, Bédar, and Cabo de Gato. As they bought or leased mines, they introduced planning and systems for orderly exploitation. From the beginning, they made large capital investments and tackled major developments. Their corporate approach was in marked contrast to the Spanish way of doing things.

Their representative in Spain was Luis Figuera y Silvela. He knew the Sierra Almagrera well as he had been associated with the company which had operated the pumping station in the Jaroso Valley. La Compañía de Águilas re-opened the pumping station when they took over the running of the mine Constancia.

La Compañía de Águilas did things on a grand scale, in the case of in the Barranco del Francés, literally changing the face of the mountains. Here, they blasted out a broad swathe of rock to create a wide plaza in order to build a new pumping station and carved a deep cutting through to the next valley wide enough for an accommodation block and access road.



The remains of the pumping station at Barranco del Francés as it is today.

As well as acquiring mines in the Jaroso, they also built an administrative centre there, controlling their interests of Justicia, Gloria and San Luis Gonzalez on the southern side of the valley, together with their interests in Republica and Carmen de Gómaz Larios in the Barranco del Chaparral.

Not to be outdone, the Dos Mundos company, which operated in the Barranco del Francés, built an even more imposing headquarters, Casa Dos Mundos, in order to control their interests there.

La Casa de la Compañia de Águilas in the Jaroso. *mtiblog* *Casa Dos Mundos above the Barranco del Francés.*

As mines introduced steam power, the owners had been obliged to construct a track up to the pit head, in order to haul up the necessary boilers. These were very much individual tracks rather than lines of communication. La Compañia de Águilas realized immediately that this lack of communication in the rugged mining areas was seriously hampering operations. They constructed good solid caminos (tracks) to enable the transportation of coal and other materials up, and minerals down, the mountain. They also linked their various centres of mining activities. For the first time it became possible to traverse the Sierra quickly. Maintaining a steady 15-20% gradient and with sweeping curves, these tracks were used by mules and teams of oxen. This was the means of transport right up until the closure of the mines in 1958. The tracks are still there, partially eroded in some places but nearly all are passable on foot. The main ones are negotiable by trail bikes and buggies. They can be clearly seen on Google Earth but it is easy to lose sight of them on the ground.

The 'easy way' up to the Atayala Árabe . . .

. . . and the 'interesting' way down again.
(Villaricos is just out of view in the top-right.)

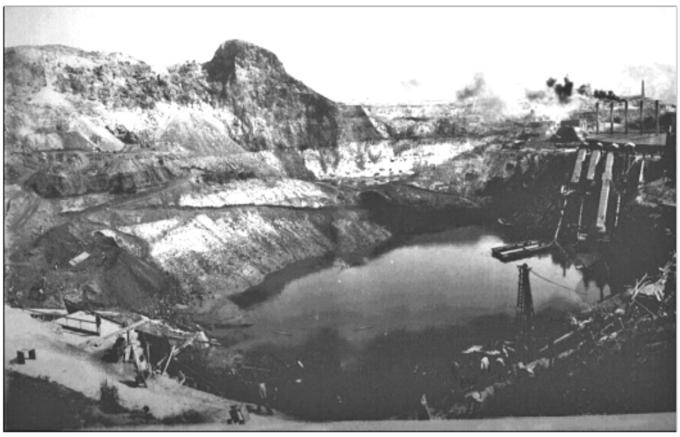
In Águilas, they constructed a port, large enough for steam ships, in order to move minerals from their interests in Mazzarón and Lomo de Bas. Within 3 years of their arrival, they were providing 8,000 jobs in the area. However, this did not last long. As a company, they had a wide range of interests in several countries, so kept a close eye on the vagaries of the international markets. They foresaw the fall in the price of silver and lead so decided to pull out. From 1886 onwards they rapidly liquidated their mining and metallurgical assets. This hasty retreat paralysed the pumping stations which in turn condemned to closure all of the mines remaining in the hands of small companies. A writer at the time lamented that "The barrancos were silent. The roads that had been crammed with pack mules taking water and supplies up and bringing minerals down were empty. You could walk without exchanging a word or seeing a living soul".

In addition to being held to blame for the collapse of the mining industry in the Sierra Almagrera, they were also blamed for the inundation of Las Rozas in 1884.

The open cast mine of Santa Matilde just behind what is now called Las Rozas was, for several years, operated by Guillermo Huelin an entrepreneur from Málaga. At a depth of 20 metres there was occasionally water ingress from the Rio Almanzora. Aware of the danger of serious flooding, Huelin maintained a buffer zone between the excavations and the river. In 1882, six years after Huelin's death his son transferred the interests of the business to La Compañía de Águilas.

Disregarding the prudence of the previous owners, and seeking to improve production and profit margins this perfidious French company compromised the barrier that Huelin had maintained. 1884 saw unusually heavy and prolonged rainfall in the area and the Almanzora was full to overflowing. The combined forces of greed and nature resulted in 1,800 litres of water per minute pouring into the workings.

All of the mines of Las Herrerías were flooded. Landslips engulfed buildings, pit heads plummeted down their shafts and huge cracks opened up. Total disaster and ruin! The aftermath was devastating. Not only had the population lost its livelihood, but the standing water harboured mosquitoes so malaria was endemic. After a failed attempt to dry out Las Rozas, La Compañía de Águilas hived off their interests in Las Herrerías and Palomares on a 99 year lease to a Spanish company on condition that they drained the rozas.



Las Rozas flooded. Rodrigo

Interestingly, the pumping machinery installed by La Compañía de Águilas in the Barranco del Francés was brought down and recycled for use in drying out Las Herrerías.

3.3. Of pozos. (In this context the translation of pozo means a shaft and not a well.)
There was a marked differences in ways that the mines were operated depending upon the money available for infrastructure. The smaller, less profitable, concessions were accessed in a very primitive manner. Sometimes there was just a single shaft which served for access, ventilation and extraction. The mine Arrojo, bordering on to the Rambla del Arteal, seems to have been one of these. In the photograph, in what would normally have been the housing for just the access shaft, there seems to be a winch mechanism. If that is the case, then the miners would have been winched down on a rope hoist, putting their life in the hands of the tornero or winch man. The chimney-like structure at the right of the canopy is a ventilation flue, where air was channelled up the side of the shaft. Using a system that dates back to at least Roman times, a section of the shaft was partitioned off to form a flue. This in turn created an air uptake and an air intake and, for this mine, seems to have been its main ventilation. There is no clear track to this mine, indicating that it was never converted to steam power. By 1890 it seems to have been had been abandoned.

The mine Arrojo as photographed by Rodrigo

Arrojo it is today

A more usual arrangement was to have two main shafts, one for extraction and one for access, and one or more ventilation shafts. The miners reached the workings via a series of ladders and platforms down the “pozo del escalado”. In the deeper mines there could be as many as eighty sets of ladders to be scaled at the beginning and end of each shift.

Many of the smaller mines operated with a manual winch for the extraction of ore. The main disadvantage of this type of winch was that the depth of the shaft was limited by the strength of the “torneros” or winch men. It was possible to have winches sited at intervals down the shaft and to bring the ore up in stages, but this made the process very laborious. The very early winch drums were simple cylinders. The drawback of these was that, as the esparto rope was reeled in, the coils travelled from side to side of the drum. As a result, the esparto basket containing the ore acted as a pendulum, frequently knocking into the sides of the shaft. To overcome this unfortunate occurrence, an ingenious type of drum was developed which was waisted in the form of a diabolo. This kept the rope and the baskets centred in the shaft reducing the risk of tipping and saving on the wear of the esparto baskets.

A manual winch in operation.

The diabolo or "saddle" drum.
Dialnet-Los Castillos Mineros

Greater depths could be reached by using a mule powered hoist, known as a malacate. Some of these were quite elaborate affairs, often covered with an esparto grass canopy. They consisted of a vertical shaft or axle with one or more bars radiating from it. A mule, or mules could be hooked up to these bars and made to walk round in circles, thus providing the motive force. A malacate had twice the lifting power of a manual winch. Apart from Carmen, the "rich mines of the Jaroso" had such hoists.

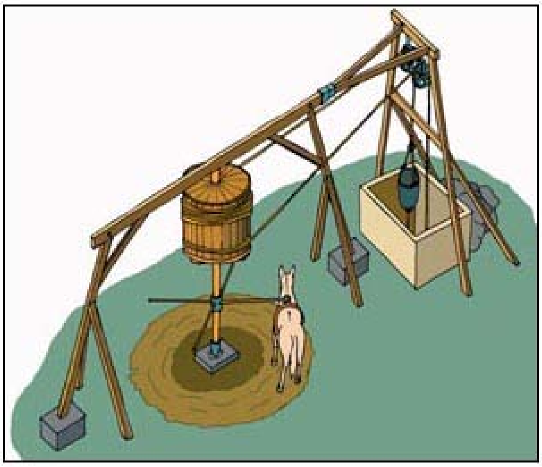
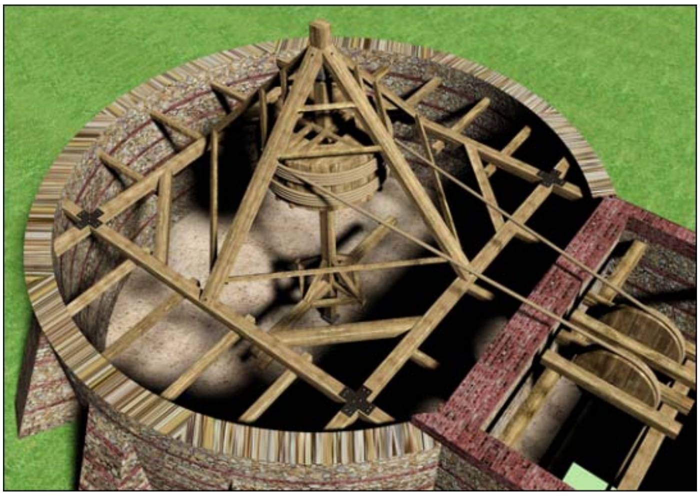


Diagram of a malacate.

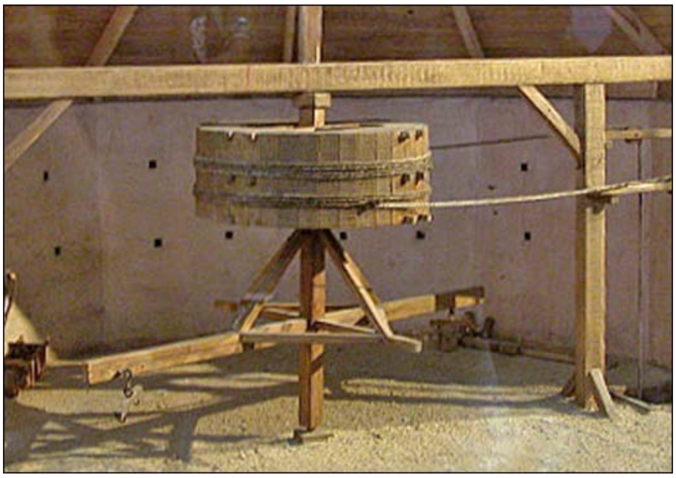
Malacate in use in the Sierra Almagrera.

Carmen had what was called a baritel, which was a variation of a malacate. Again it was animal powered. The mechanism and animal were housed in a circular, roofed enclosure. The drum of a baritel was often 6m. in diameter and the housing 10m. Carmen's baritel was able to operate to a depth of 200 metres. All that remains of it today is a section of the housing.

Remains of the baritel of the mine Carmen.



Model of a baritel showing how it operated.



The baritel of the mine San Andres in Almadén.

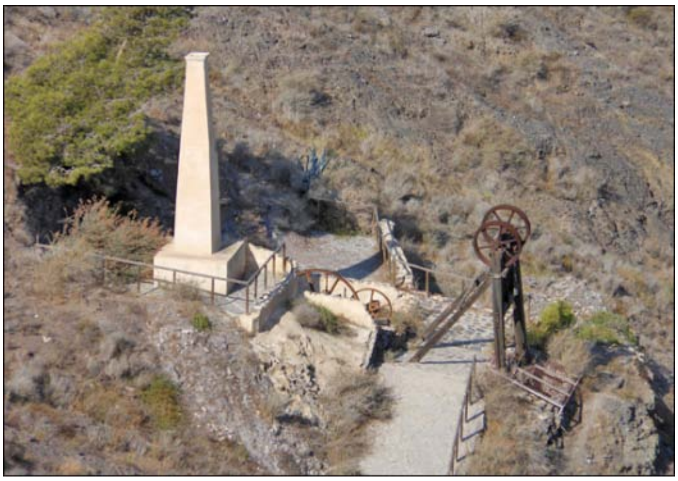
The great advantage of both the malacate and the baritel was their dual action drum, which was capable of raising and lowering a load simultaneously.

These animal hoists were remarkably efficient, so much so that, even 20 years after steam power was introduced to the area, the “rich mines”, Carmen, Observación, Rescatada and Estrella were still operating them.

Steam power came to the Sierra in 1864 when the first powered winch, complete with steel cables rather than esparto grass ropes, was installed in the Purísima Concepción mine in the Barranco del Jaroso. Far greater depths could now be exploited. Chimneys, boiler houses and, most importantly in this arid region, large water collection cisterns were constructed.

The water collection cistern of the mine San Andres.

The sign of an affluent mine was a chimney and the classic pit head winding gear. Amazingly, one of these very early, wooden, head frames has survived. All of the others, like everything else in the Sierra have been scavenged. It is very rare to find a scrap of metal or a plank of wood anywhere in the mountains. The winding gear of the Encantada mine, in the Barranco del Chaparral, has been partially restored. The boilers and engine are exposed as the engine room was not re-built. The head gear has been reinstated. It is easy to get to and is well worth a visit.



A general view of Mina Encantada.

Mina Encantada's pulley sheaves and above, winding drums.

Although simple, these early timber head frames were very efficient. They could be operated with either flat metal cables or flat esparto ropes. In many cases they lasted for the working life of the mine.

The engine and boilers of Encantada are interesting. 80% of the steam engines in the Sierra were of this type, designed and installed by a Belgian engineer named Paul Colson. This particular 10 Hp. engine was manufactured for him by the Reading Iron Works Ltd. They were assembled on site and their small sized boilers could be transported up the mountain with comparative ease. (Unlike the Humbolt boiler which required a team of a dozen oxen to haul it up to La Guzmana.)

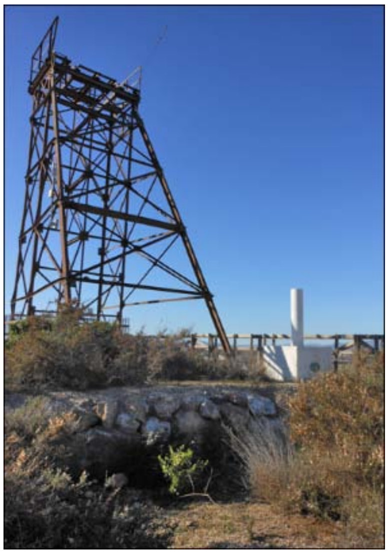
La Guzmana. Rodrigo captured the arrival of a boiler at La Guzmana hauled by a team of oxen.

The small boilers favoured by Colson.

All that remains of a compact 10 hp. engine.

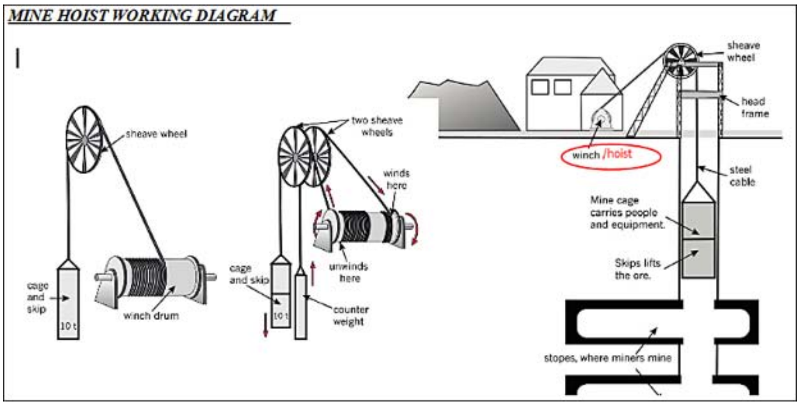
Colson's engine was very economic in terms of water consumption and, in addition, was relatively inexpensive. He would take a down payment and the balance in stages, as a percentage of the value of the mineral extracted over a given period. (An early form of the never-never!)

Mines which had a relatively long life span substituted the timber head frame for a larger, more elaborate, metal one. The only surviving example is the Pozo Susana frame, minus its winding gear, in Las Herrerías which was operated by a 50h.p. motor.



Pozo Susana above Las Herrerías.

Wherever you come across a large, rectangular shaft and the remains of a building next to it, you can be sure that you're looking at the remains of an engine room and pit head. Because the buildings which housed the engines and winding gear were solidly build to withstand the vibrations and stresses and strains, they are often the only remains left standing.

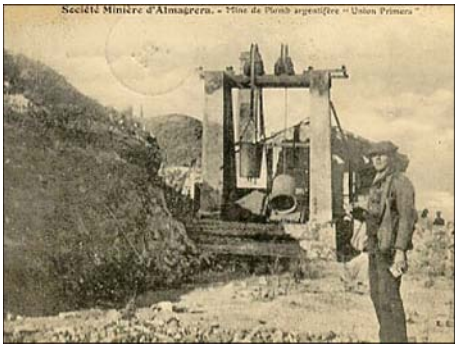


The buildings housing the winding gear needed to be solidly built.

Above, winding gear of the mine Paraíso.
Rodrigo.

A later development was that shown in the picture of the mine Union Primera in 1905. Here, the head frame is mounted on a low wall and the wooden buckets are emptied without the need to remove them from the hoist.

Union Primera.
Moran.



There are several examples of this type structure for example, San Andres near Pico Tenerife, and Mesías in the Barranco del Francés. They are the intermediate development between the very early winches and the tall castilletes, of which, more in the next section.

Above, the head-frame supports of San Andrés (J A Sanchis) and, right, Justicia.

3.4. and castilletes.

There is no mistaking the "castilletes de mampostería", or masonry pulley supports. These were built of roughly mortared, waste rock, which was then smooth rendered. Their height varied, but their function remained the same. These graceful towers are the landmarks and signposts as you explore the Sierra.

The supports for Mina Ánimas (left) and for Mina Santa Isabel (above). These two mines guide you up the Jaroso Valley.

Rafaela (above left) stands guard over the right fork from the Jaroso into the Barranco de Fernádez, on the way up to the summit. Numancia (above right) towers above the Barranco de Las Palomas. *mtiblog*

These castilletes are not to be confused with the supports for aero cables like these on "Television Hill" and in the Barranco de Las Palomas.

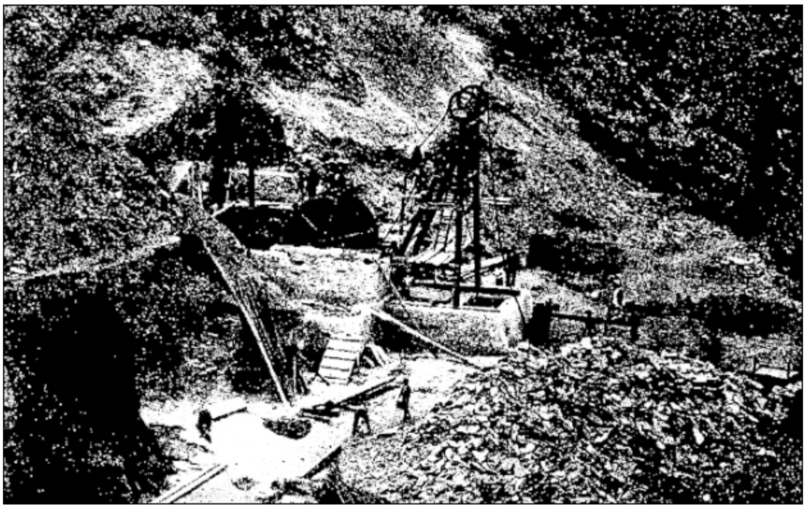
("Television Hill", so-called because – incredibly – someone went to the trouble of transporting and then dumping a large television half way up the track. It's skeleton remains.)

Aero cable supports on "Television Hill".

Aero cable supports over the Barranco de Las Palomas.

The following photographs illustrate the development of the method of ore extraction through the 19th century. The mine República started life with a manual winch as seen in the first photograph. However, if you look carefully, to the left of the picture, you can see the sheave wheels of new, powered, winding gear waiting to be installed. In the second picture the head frame has been erected and the extraction shaft reinforced.

The manual winch of Republica.
Rodrigo. Taken from 'Tiempos de Plata y Plomo', Enríque Fernández Bolea.



Erecting the powered winch at Republica.
Los Negocios de los Fernández Manchón. Enríque Fernández Bolea.

It was probably upgraded by the Compañía de Águilas and then upgraded again in the 1950's. It would have certainly have needed something bigger than the original Colson engine to power it!

Republica as it is today.

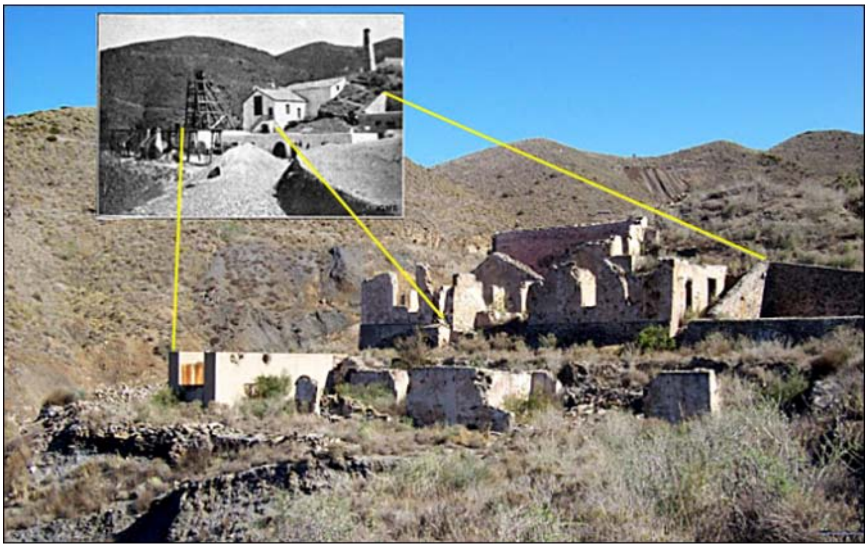
Below, the arches where the ore was taken out. *mtiblog.*

The ore was taken from the hoist via the arches.

The best example of these arched extraction points are to be seen at the mine Fuensanta.

The gated arches to the shaft of Fuensanta.

There are some interesting castilletes in the Barranco Hospital de Tierra, on the way up to La Guzmana. The mine Independiente had the type of head frame shown. The massive walls simply supported a frame and sheaves. Underneath, is a dual purpose shaft, used for extraction and access.



Independiente, then and now. *Photo. A.G. Jódar.*

The shaft of the Independiente was used for access and extraction. The ladders and platforms can be seen behind the guide rails of the lift cage.

Photo. A. G Jódar.

Also in the Barranco Hospital de Tierra, is the mine Patrocinio, with its leaning towers of Piza. There are insulators attached to the side of one of the castilletes, indicating that it was powered by electricity in its later years.

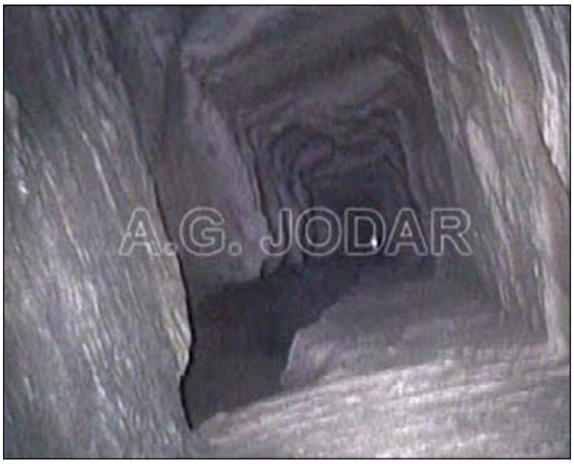
The leaning castilletes at Patrocinio. *Photo. mtiblog.*

The winding gear at these mines would have looked like this.

3.5. Ventilation.

Adequate ventilation is a permanent problem in mines and, with very few exceptions, natural ventilation systems were used. I have done some research into how it was achieved in the Sierra. I think that for the most part, systems of natural ventilation were used. This was probably due to a variety of factors such as avoiding the need for capital investment, no running cost and limited access to technology.

Many of the shafts in the Sierra are ventilated by means of a grooved integral channel running down the side of the main shaft as can be seen in the picture of Constancia's shaft. This channel would have been bratticed (partitioned) using a wood and gypsum mix, similar to wattle and daub, or canvas cloth. Wood was in short supply throughout the Sierra so the use of wooden planks to effect the partition was uncommon.



The shaft in Mina Constancia would have been bratticed with wattle and daub.
A G Jódar

Other shafts have a ventilation channel which looks to be separate from the main shaft as can be seen in the pictures taken by A G Jodár using a remote camera.

The ventilation shaft (on the left) in Elisa is separate. This is looking down from the top of the shaft. A G Jódar

The ventilation shaft at the bottom of the main shaft. A fire could have been set in its base.
A G Jódar

I am inclined to think that, as the shaft was being sunk, a groove was cut and then mortared to create two distinct shafts. It is also possible that fires may have been set at the base of these channels to create an updraught as was the practice in other countries.

There are several of these white topped ventilation shafts in the Barranco del Francés and in the Barranco del Jaroso.

Ventilation shafts in the Barranco del Francés and (below) in the Barranco del Jaroso.

There are also several ventilation shafts that are just deep holes in the ground. These are the most dangerous of all the shafts in the Sierra as there is no warning of them.

Beware!

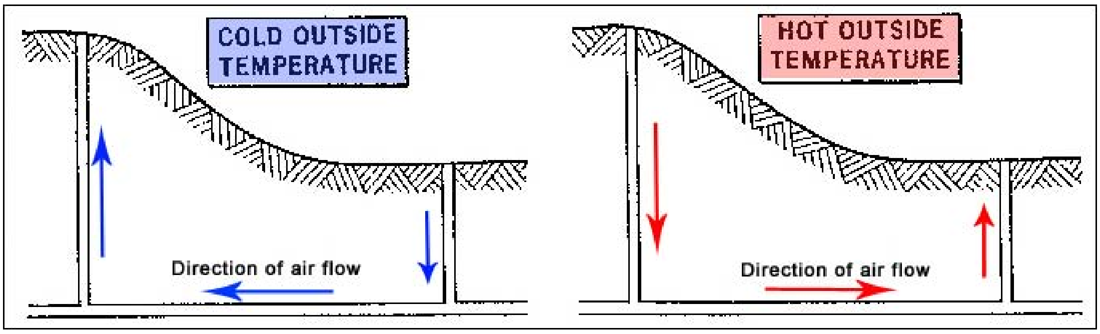
Originally these ventilation shafts had a cone-shaped cap with a hole in the centre as shown in the pictures on the next page. Over the years these caps have collapsed and fallen down the shafts leaving only an open – and unguarded – hole.

Ventilation shafts originally had domed caps. This is the only intact example I have found, hence the warning.

So, how does natural ventilation work? The proper term for it is buoyancy driven ventilation. It is due to the differences in density of interior and exterior air. These density differences are, to a large part, due to temperature differences. When there is a temperature difference between two adjoining volumes of air, the warm air will have a lower density and be more buoyant. This causes it to rise above the cold air, creating an upward air stream.

The problem with the system is when the outside temperature changes. Good ventilation occurs in the winter, as can be seen in this photograph, with warm air condensing out above a ventilation shaft on a January morning.

On a hot summer's day, the results of natural ventilation are not so apparent. There are also problems when hot days become cold nights. The air flow tends to reverse with the fluctuation in external temperatures.



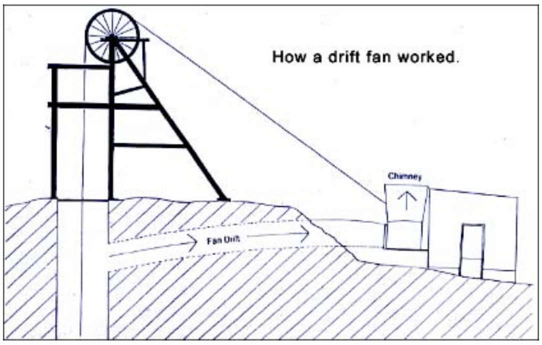
I believed I had found evidence of forced ventilation at the top of "Television Hill" when, after years of puzzling over the feature shown below, I thought I had found the answer.

Location of the mystery feature.

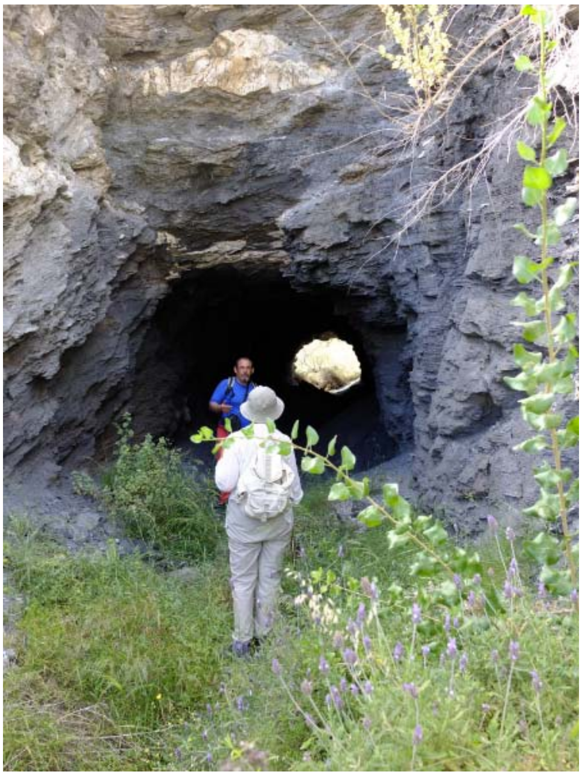
Up close.

Left, reconsruction of A Capell drift fan.

Below, how a drift fan worked.



During a visit to the Black Country Museum in Dudley I saw a reconstruction of a Capell drift fan and was sure that my mystery feature was the remains of one. The nearby Centinela mine had been a drift mine in the 20th century, extracting iron ore rather than galena and there are numerous brick-arched drift entrances nearby which reinforced my theory. Once again Señor Jódar, while understanding the plausibility of my notion, told me that it was simply a means of diverting the flow of rainwater down the gulley. Years previously he had passed a remote camera through it showing that it was no more than a pipe made of bricks. All was not lost though. He told me about the only incidence of forced ventilation that he knew of and kindly took me to its location, the mine Monserrat high up in the Jaroso valley. There, near to the tunnel through which the old road up to the top of the mountain passed, is an unusual shaft. Steps are cut into the side, so it was obviously used for access, but also up the side is a ventilation groove that would have been bratticed.



Left, the tunnel by Monserrat, through which the old camino passed.

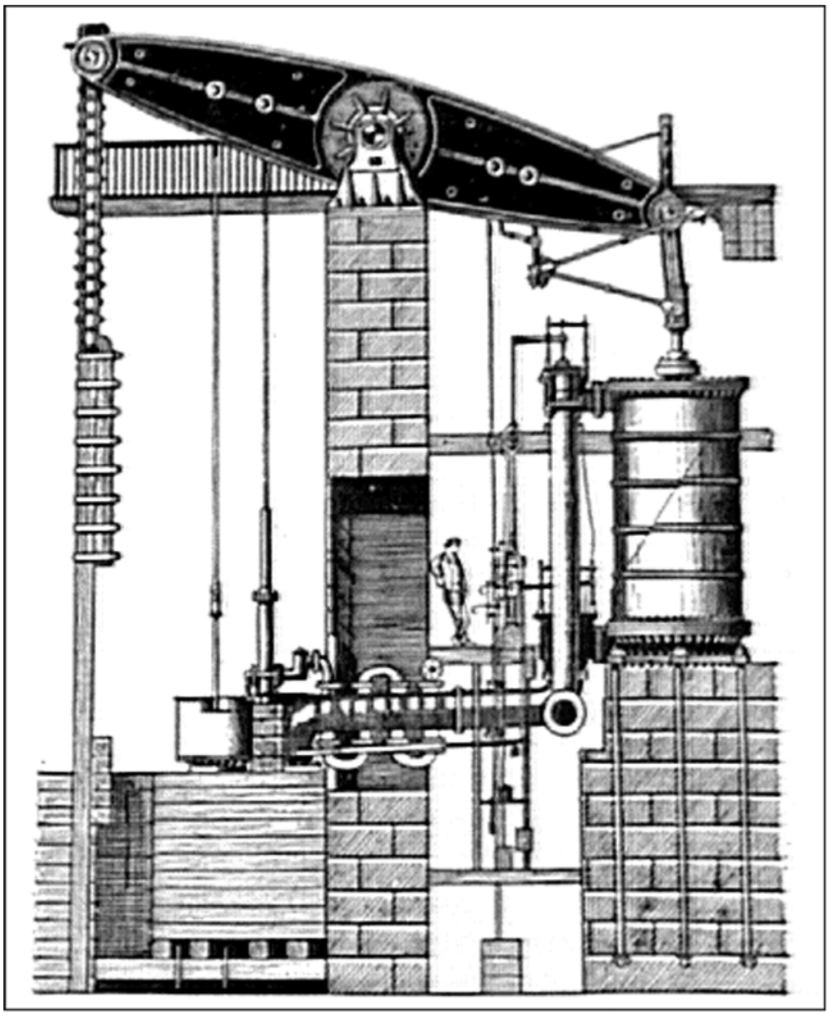
The shaft, with steps cut into it and the ventilation channel running up the left-hand side.

Nothing unusual there then, except for the fact that the channel extends into a small building next to this shaft. It would be quite easy to mistake this for a latrine, apart from the fact that the hole in it gives directly into the adjacent shaft!

The end of the ventilation shaft in the ruins of the small adjacent building.

The only explanation for this set-up is that there was some form of forced ventilation mechanism housed in this small building. I have no idea how it was powered and could have been a simple hand-operated fan or a more complex mechanical one.

Chapter 4. The Enemy Below



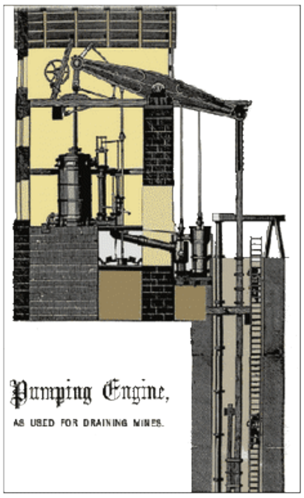
4.1. The Desagüe del Jaroso.

Rodrigo.

What really sparked my interest in the mines was the puzzle of the "lost village" of San Juan lying abandoned like a ghost town in the mountains. Everybody who has walked through it forms a picture of what life was like there, with its row of houses, its church etc., etc., What I found out came as a great surprise but I had to go back to the early days of exploitation for the explanation.

In 1845, in the Barranco del Jaroso, workings in the mine Ánimas had reached a depth of 150 metres when they encountered a problem. Small trickles of water started to appear. These were contained initially by primitive bailing methods, gates and dykes. As they mined deeper, following a productive vein, alarming amounts of water appeared. The same thing then happened in neighbouring mines.

The Sierra Almagrera is arid and yet there was this problem with water. Initially, the water was presumed to be sea water, but measurements showed that the water level in the mines was 30 metres below sea level, in addition, analysis of the water proved that this was not the case. What they discovered was a large hot spring, which was located at the base of the mountain. This was erroneously visualized as a large underground basin, that in time, and with sufficient drainage, could be eliminated. The presence of such water was not surprising since the rock formations and minerals present indicate a geothermal system. In fact, Ezquerra del Bayo predicted it a few years before the water was reached.

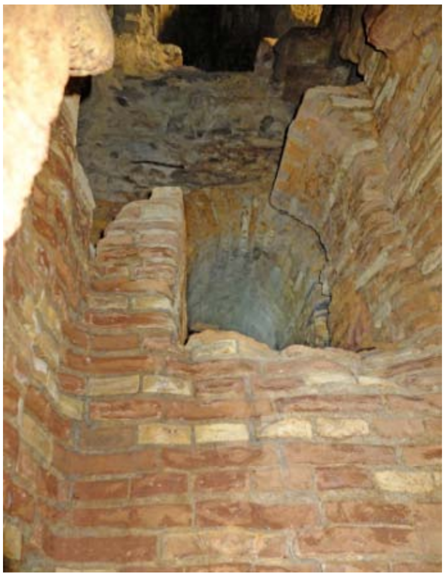


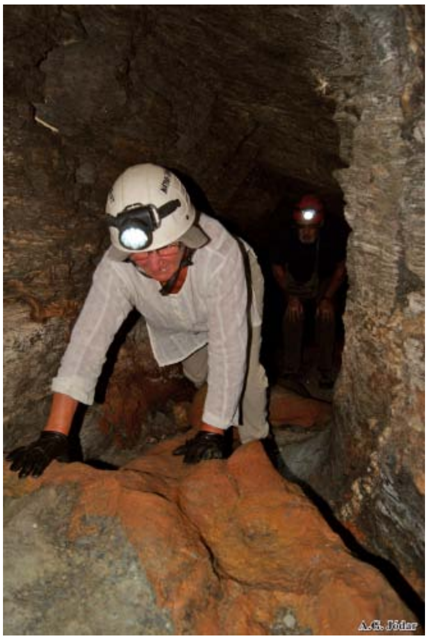
There appeared to be two possible solutions. One, draining by pumping or two, opening a sloping tunnel to discharge the water into either, the Rambla de Muleria, or, into the sea, depending on the position of the mine. The point of maximum depth was the mine Constancia which was closer to the rambla than to the sea. Using the lie of the land, and existing mine shafts for ventilation the construction of a socavón, or tunnel, was proposed. It was to have run from Ánimas and would have discharged into the rambla at la Boca de Mairena near Los Lobos. Work was due to start in 1843 and be finished in 1846. However, due to a lack of agreement between the mine owners, this logical and relatively inexpensive project never got off the ground.

Flooding became a serious problem. In 1846 a consensus was reached and a new-fangled steam engine, to drain the mines was purchased. The parts for which were laboriously hauled up the mountain by a great team of oxen. As soon as it entered service it was realized that there was more water than previously thought. In addition, the salts and minerals in the water encrusted the pipes causing frequent breakdowns. The water was pumped up to the surface and discharged into a short tunnel which links the pumping station to the Jaroso rainwater culvert, (There are several apertures, one above the other, below the pumping station and I assume that the outflow was through the lowest one.) the water was then used in the lavaderos that were situated on the valley floor. An idea of the magnitude of the encrustations that caused so much trouble for the pumps can be seen on the floor of this tunnel.

Left, water was probably pumped out through the lower aperture into the tunnel under the present course of the Jaroso rambla.

Right, the higher aperture may have been for ventilation.





Left, the encrustations formed by the salts and minerals in the water can clearly be seen on the tunnel floor

Right, the tunnel leading to the desagüe is a classic coffin adit.

The entrance to the combined rain and pumped water tunnel is on the right.

In 1849 work started on a tunnel, the socavón Riqueza Positiva, to drain the water to the sea.

The line of the tunnel under the Sierra.

400 metres had been drilled when there was a change of mind. A board was set up consisting of 2 members from each affected mine and two new boilers were purchased and pumping recommenced.

Breakdowns caused by corrosion continued. In December 1854 a group of workmen were down the main shaft clearing encrustations early in the morning when, because they were cold or to improve ventilation, they lit a fire! 30 sections of wooden platforms and ladders went up in flames. The ventilation shafts of the neighbouring mines had to be closed and it was not until the afternoon of the next day that the fire was extinguished. The fire-setters were not only fired but imprisoned.

Work recommenced on the Riqueza Positiva.

The socavón started 177m below Constancia and passed through the old workings in adjacent mines, going under San Cayetano to the seaward side of the Sierra. This 2 metre high and 2.5 metre wide tunnel maintains a gradient of 1 in 1000, its outfall is 2 metres above sea level in the Cala del Peñón Cortado. The water flowed through wooden trunking set in the floor. There are several lumbrera or ventilation shafts along its length, the first situated just a few metres from the exit.

Looking up through the first lumbrera. *Mti.blog*

The interior of the tunnel looking towards the exit. Mtiblog.

The brick kiln.

On the coast side is it reinforced by brick arches. The bricks were made in the specially constructed, nearby, brick oven. It was hoped to use the gallery as a corridor for moving minerals from adjacent mines to the coast, but economic difficulties and changes of ownership meant that this never happened. It is possible to walk for quite a way into the tunnel before it is blocked by a fall.

The Cala del Peñón Cortado seen from above.

Entrance to the tunnel from the beach.

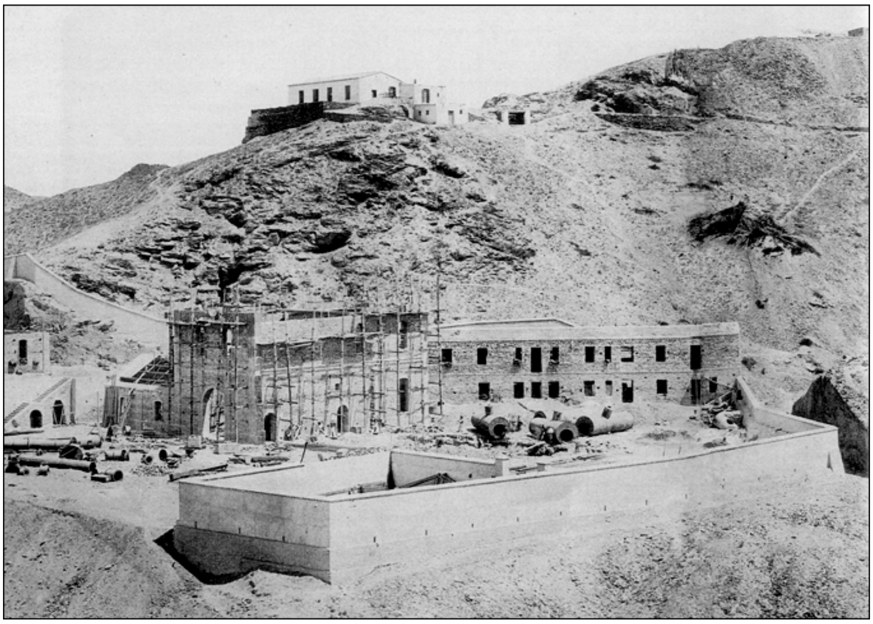
The cove is named after the "Peñón", or crag, that was "cortado, or cut through, to give access to the socavón.

Over the years, work continued on the desagüe, pumping engines were modified and replaced. A new shaft was sunk. A larger condenser installed. Drainage was slow, breakdowns were frequent It was money down the drain. The mine owners refused to pay the 10% levy imposed by the drain operators and in 1879 it closed.

Two years later it was reopened by La Compañia de Águilas who made some improvements but in 1886 it was abandoned for the final time.

All that remains of the Desagüe del Jaroso today.

4.2. The Desagüe del Francés.



San Juan under construction. *Tiempos de Plata y Plomo. (Bolea et al.)*

So to the "lost village" of San Juan, situated at the heart of the Barranco del Francés. With its row of terraced houses and the remains of a large house, one can be forgiven for imagining it as a village, peopled by miners and their families. It was, of course, nothing of the sort. It was the second of the pumping stations in the Sierra, trying to prevent the mines from flooding.

In the 1880's, the centre of exploitation was shifting from the Jaroso to other areas. The most important of these was the Barranco del Francés, where the Compañia de Águilas was working several of the concessions.

San Juan is their legacy. They blasted out the wide flat area around the San Juan shaft, where they built the pumping station's pump and engine house, together with a large boiler room, water collection and storage tanks. Above and behind this plaza, they created a second tier to accommodate the plant director's house and offices, accessed by a flight of steps.

San Juan, as it is today. The director's house is on the raised second tier.

The workers lodgings and canteen were constructed on the side of the roadway which they cut through to the Barranco Chico de Torre.

The accommodation block as it looks today.

An interesting feature of both desagües is the sloping condensation channels from the boilers. The Jaroso one is stepped, while that of San Juan is straight. Both had a chimney at the top and, presumably, the San Juan one had a covering. Sloping condensation tunnels from boilers are a feature in the Sierra and I suspect there was a water recuperation element to them. There is a second, sloping channel, leading up towards the mine Isabelita. This one, however, was to increase the updraught from the ventilation shaft in the area by the curtain wall.

*Left, the condensation channel from the boilers and,
right, the ventilation channel running up towards Isabelita.*

The San Juan shaft, part of the Crescencia concession was extended to a depth of 220 metres and widened to 3.30 metres by 2.10 metres. It was twinned with the ventilation shaft sunk over by the curtain wall.

The San Juan shaft and the remains of the engine room

The water at the bottom is 35^{O} C. and is red.

The rough sides of the secondary shaft.

The water was pumped out through here.

Water for the boilers proved to be a problem for the Compañía de Águilas. The cost of the water brought up on the backs of mules was exorbitant and there was often insufficient rainfall to meet the demand. The solution was to make as much use as possible of condensed water which they supplemented with 5% seawater. This was pumped up from the same cove as the exit for the socavón Riqueza Positiva. The pipe can still be seen after certain sea conditions. I have no idea what line the pipe took: part way through the socavón and then through existing mine workings is one theory. It could also have passed through the brick arch visible in the photograph below and then taken a completely different route. Pie y Allué in, an article he wrote for 'La Revista Minería y Metalúrgica 1883', tells how a 10hp locomóvil (a steam engine on wheels similar to those used to power agricultural machinery) was used to power the pump. The locomóvil or the pump could have been housed in the edifice in the photo below.

Possible remains of the pump house in Cala del Peñón Cortada.

The pipe which carried seawater to the desagües is occasionally exposed. *A G Jódar.*

Using seawater seems to have been a short-term solution because the publication 'Minero de Almagrera' of 26th November 1884, printed an article about La Compagnie de Águilas sinking a well on the bank of the Almanzora and laying a pipe to the desagüe in order to fill the water cisterns. I have not been able to extablish the location of the well or the line of the pipe.

The pit parallel to the shaft

Another view of the engine house.

One thing which puzzled me about the site was the remains of the engine and pump room house. The pit where the fly wheel rotated is positioned parallel to the shaft and not at 90 degrees to it as one would expect.

On further research, I found out why it was arranged in this way. The pump that was installed in 1884 was a Kley Pumping Engine, which, as can be seen from the diagram, needs to be positioned alongside the shaft.

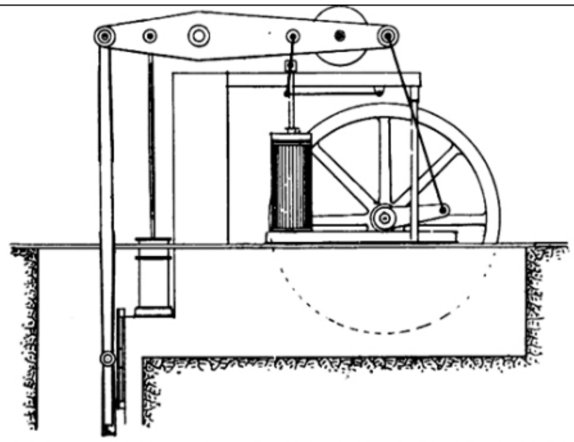


FIG. 85.—Kley's Engine, in which the fly-wheel does not turn completely round when going slowly, but turns backward and forward, the piston not making a full stroke. When running fast the engine works as an ordinary rotative engine.

Diagram of Kley pump
Henry Davey. 1900

Restored Kley steam pump at the Idrija Museum.

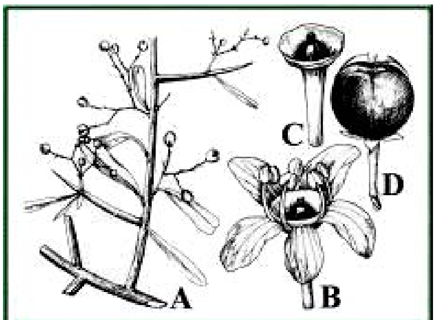
A Kley pump has been restored in Idrija, Slovenia. It began service in 1895 and was last operated in 1948. The one at San Juan operated for a mere 13 months, closing 3 days before the desagüe in the Jaroso. It was designed to lift water to a maximum of 221 metres, so was working at the limits of its capability in a 220 metre shaft. There was talk of pumping the water out through a drain lower down in the Barranco de Sima. However, in 1886, La Compañia de Águilas pulled the plug. In the case of both desagües, it was the mine owners refusal to pay for the very infrastructure they needed that sealed their fate. The mines were inundated and once more the industry was in crisis.

Two separate types of water caused problems in the Sierra Almagrera. The first was that encountered is common to virtually all mining activity after reaching a certain depth. In this area it was referred to as 'las aguas frias', or cold waters. In other words, rainwater. This filters through fractures in the rock, the mine workings and, where it is porous, through the rock itself. For the most part, this cold water can be drained by gravity, or raised to the surface or a combination of both. In the Sierra it was the other type, the thermal waters as hot as 50ºC that caused far more trouble. This water accumulates in fissures in the veins, filling the space previously occupied by gases given off during the mountain's formation. Such spaces, where they are between the body of the ore and the next strata can be relatively small. These were known as 'huecos', or hollows by the miners. Larger spaces, which contained considerable amounts of water were known as 'soplandos', or blow-holes. In places there is a mixture of the two types.

The method adopted by both the Jaroso and Francés pumping stations was to sink shafts until the water level was reached and then to extend the pipes as the level dropped. When they tried to drive levels to tap into the thermal waters they ran into problems. Once they encountered a fissure, the heat and corrosive nature of the water made it virtually impossible to continue with the drive. This resulted in only those mines in close proximity to the pumping stations benefiting from its efforts. Those further away saw little return on the levy they were expected to pay.

4.4 The Desagüe del Arteal.

The only sign that indicates the presence of one of the most important sites in the Sierra Almagrera is the one that reads 'EL ARTEAL poblado minero' (El Arteal mining complex). There used to be signs on both sides of the road but the one in the photo on the right was knocked down and lay in the undergrowth for a while before it was 'collected' for scrap. The name El Arteal comes from Arto, the Spanish name for the evil, thorny shrub, Maytenus Senegalensi, which grows abundantly on the site.



Maytenus senegalensis : A, branch x ½ B, flower x 8 ; C, carpel x 8 ; D, fruit x 4.

Above and right, Maytenus Senegalensis.

The closure, in 1886, of the two previous pumping stations had meant that the level of the water in the mines had been rising at the rate of 1cm. every day, having a serious impact on both the mines and the foundries. In 1890 a commission was set up to investigate the possibility of draining and re-activating the mines. One of its first steps was to petition the Government to to enact a law making it compulsory for every individual, or company, working in the Sierra to contribute to the cost of de-watering the mines. With the commission's success resulting in a contribution of 16% of the gross output of the mines it then looked at the likely amount of water that had to be dealt with. They concluded that 3000 litres a day would be the target. They wanted the level to be dropped by 80 metres initially and then down to 100 metres within four years.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Los Imperios
Sociedad minera para explotar y beneficiar las minas
"BRANDT Y BRANDAU" Y "SIRET"

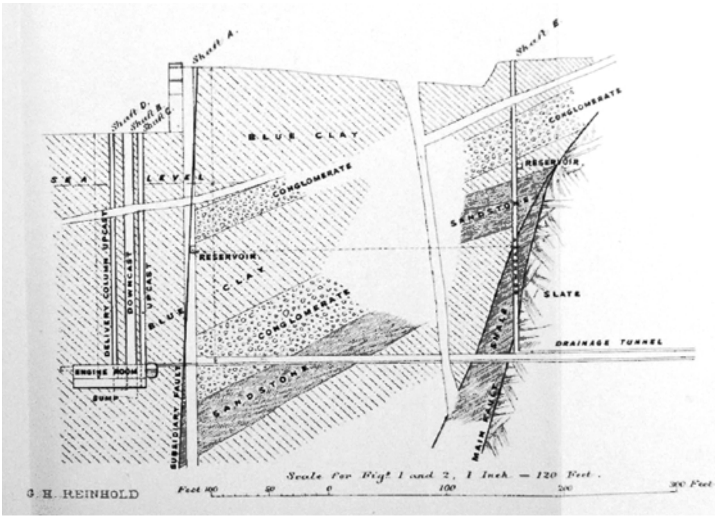
The project was put out to tender and various companies submitted bids, proposing a variety of schemes, most of which involved raising the water to the level of the Riqueza Positva and creating new socavóns linking to it. In the event the contract was awarded to Alfredo Brandt and Karl Brandau, whose company would also build the 19.8 kilometres Simplon Tunnel linking Switzerland and Italy. On winning the contract Brandt and Brandau in association with Luis Siret, formed a company called Los Imperios.

Hastial Vol 2 2012.

Brandt adopted a radical approach to the problem. He looked to place his pumps underground and channel the water to them. After a careful survey of the area he chose El Arteal as the place to site the new pumping station. There were several reasons for his choice. Firstly, it was at the base of the Sierra rather than half-way up it. Secondly, a 1.5 metre fault had dislocated the slate at the base of the mountain. The dislocated section was overlaid with clay, similar to London Clay, and was impervious apart from some thin ribbons of conglomerate close to the surface. Water in the conglomerate was not thermal water, although it did smell of hydrogen sulphide. Thirdly, there was a wide ribbon of conglomerate on the other side of the section which had itself been dislocated by a small fault. The new installations were sited at the end of this ribbon. The shaft of the mine Puente Luchana was chosen as an auxiliary shaft as it extended 20 metres below the level of the standing water in the mines.

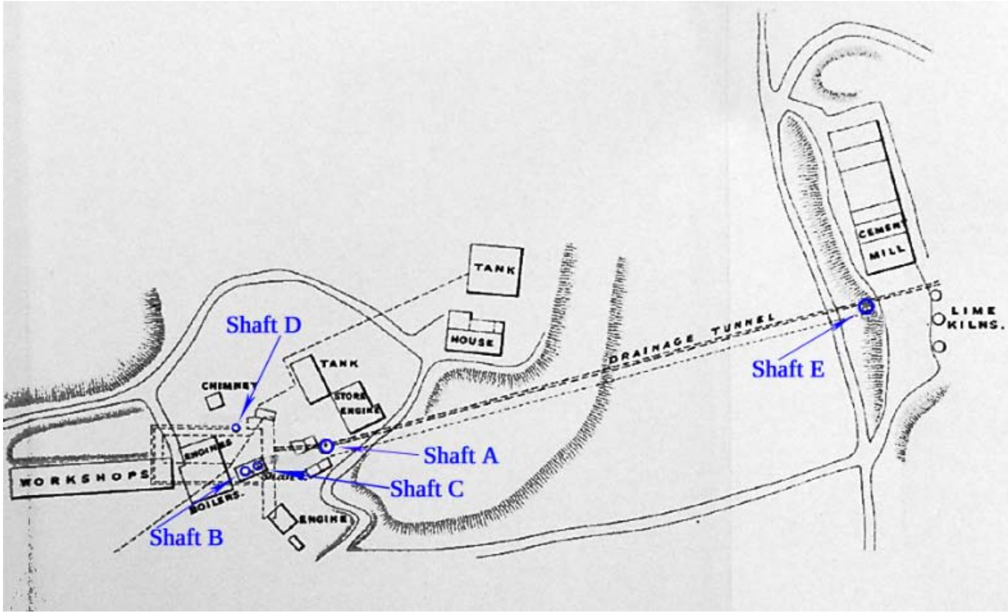
The Puente Luchana mine is at the bottom right.

The Puente Luchana's shaft.



Cross-section showing the geology and positions of the 1st phase shafts and tunnels. *Reinhold*

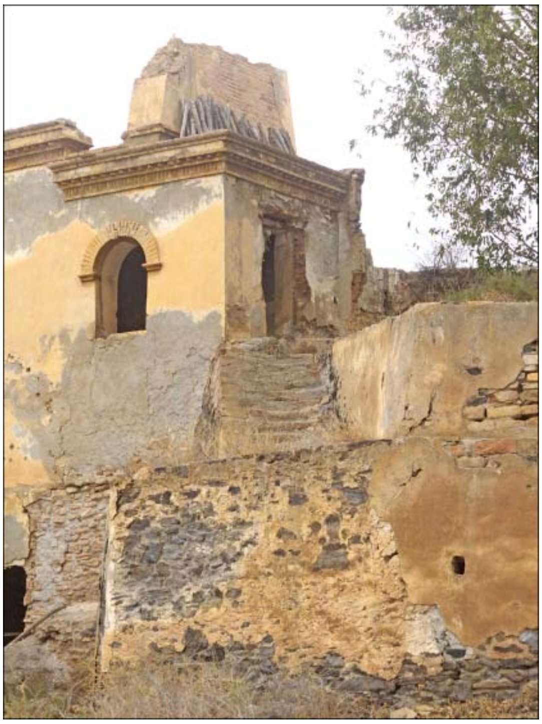
El Arteal was developed in three stages as the magnitude of the problems they faced became clear. The first phase was the sinking of the five necessary shafts and the driving of a tunnel to collect and channel the cold water to the underground pumps.



Ground plan of the 1st phase. *Reinhold.*

The first shaft, Shaft A on the plan, was named Pozo Encarnación after Encarnación Garcia de Cuélo, who gave the land to the company. The beautiful building was erected around and above the shaft and winding pulleys were installed.

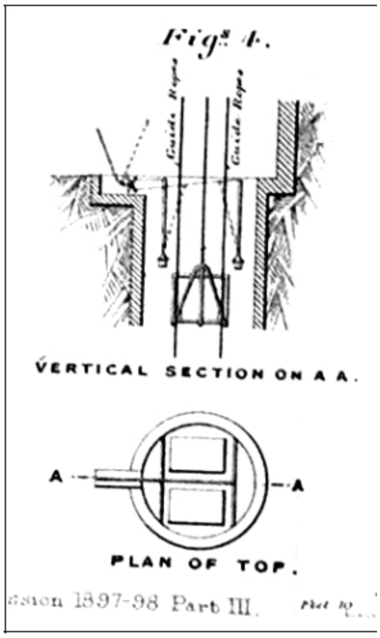
All that remains of the beautiful building that housed Pozo Encarnación.



The downcast shaft, B, and the upcast shaft, C, were then excavated simultaneously. Because of their close proximity it was possible to ventilate one by means of the other, using 'holings' at intervals, then closing these openings later. The elliptical upcast shaft was named Pozo Ana and was sunk to a depth of 117 metres and served as the main ventilation shaft for Encarnación and the engine room. The circular, 120 metre downcast shaft, was known as Pozo Juala meaning cage shaft, because it was fitted with cages capable of bringing spopil wagons to the surface. The delivery shaft, D, up which the water was raised to the surface, was fitted with ladders in case of any failure of the winding gear in Encarnación or Juala.

Left, Pozo Ana. The chimney above the shaft was added at a later date.

Right, diagram of the guide cables for Juala's cages. *Reinhold.*

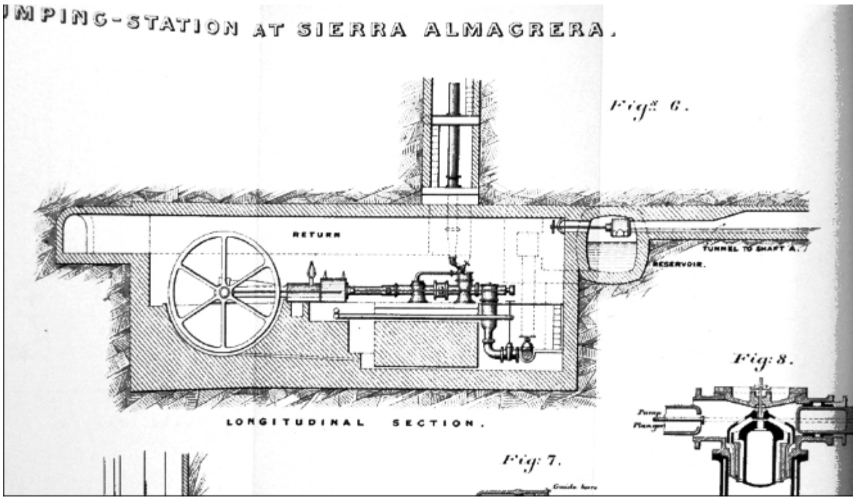


Left, back wall of Pozo Juala. This shaft has been remodelled many times over the years and is now completely sealed.
Above, The top of the delivery shaft up which the water was piped to the surface.

Above, the delivery shaft seen from below.

Above, all four shafts. The boiler room is on the left, the delivery shaft is above left, the remaining wall of Juala is in the centre with Encarnación above it and Ana on the right.

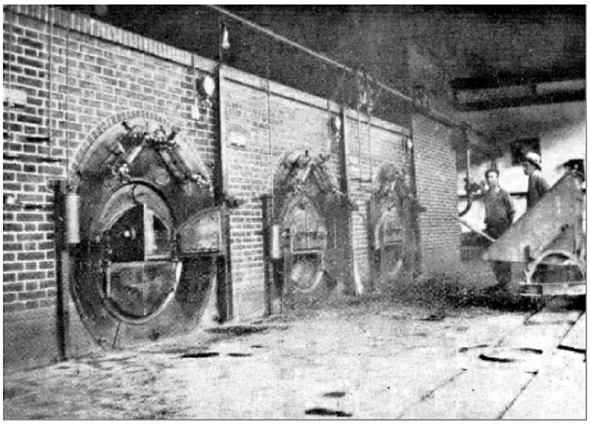
Once work was completed on Pozo Juala the steam pipes were fed down to the engine room which had been constructed below and the pump was installed.



Pump. *Reinhold*

A fifth shaft, E, was sunk 200 metres from the others, near to the mountain, to serve as a ventilation shaft for the tunnel that would bring the water to the pumps in the engine room. As this ventilation shaft was being sunk they encountered a layer of conglomerate which, despite being close to the surface, was water bearing. As soon as the shaft cleared the band of conglomerate a reservoir was built to contain the water. This was then tapped off and raised to the surface in kibbles (buckets) alongside the spoil from the sinking.

The power for all these works was provided by two Cornish style boilers, which were a temporary measure as the boiler house had been built to accommodate three larger boilers which were installed when the plant was ready to enter service.

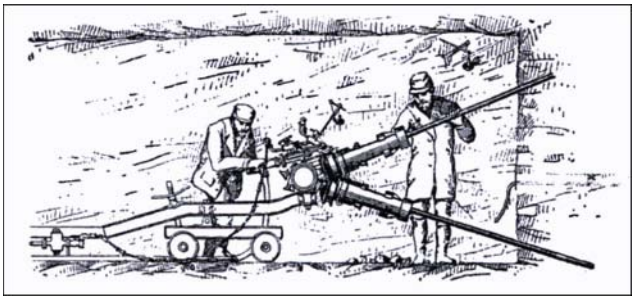


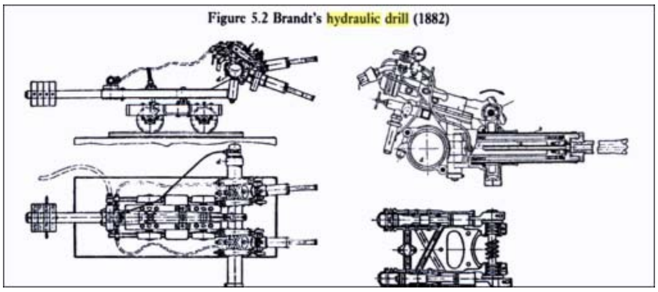
Above, the three larger boilers. The steam-pipes can be seen running into Pozo Juala. *Hastial Vol 2 2012.*

Above right, the remains of the boiler house today.

Right, the traces of the turntable for the coal wagons.

The water collection tunnel, or conduit, was driven at a depth of 85 metres below sea-level. Both the bricks and the mortar used to line the tunnel were made on-site. Flagstones were laid along the tunnel's length on which the wagon tracks were laid for the removal of spoil. Refuges and passing places were created at intervals to allow the passage of full and empty wagons and to provide shelter when explosives were used. On reaching the slate of the mountain temperatures rose considerably and the water from the layer of conglomerate in the ventilation shaft was allowed to fall as a cooling spray. As work progressed a proper water jet was used and set up about 10 metres from the work face, then as temperatures rose even further, the water was allowed to play on the faces of the workers. At 50 metres into the slate a fissure containing thermal water was encountered and drained lowering – slightly – the water level in the mines. The rate of progress through the slate, using traditional methods, was 1.30 metres a day. The inclination of the strata was unfavourable, and likely to slow the rate even more, so the decision was made to use rock drills. As far as I can ascertain, this was the first time they had been used in the Sierra. Certainly, the men operating them had never done so before although it seems they soon became quite skilled spurred on by generous bonuses. Naturally, Brandt Hydraulic Rock Drills were used since he had invented them and had used them in other tunnelling ventures. Their use speeded up the rate of progress to 3 metres a day.





Brandt Rock Drill *Drill diagram*

From 'Innovation and the Rise of Tunnelling'. Graham West

A deep well was sunk on the banks of the Almanzora river and a pumping station built, fitted with a Worthington pump and boiler. 2,000 metres of Mannesmann pipes carries the water to El Arteal, where it was used to power the hydraulic drills.

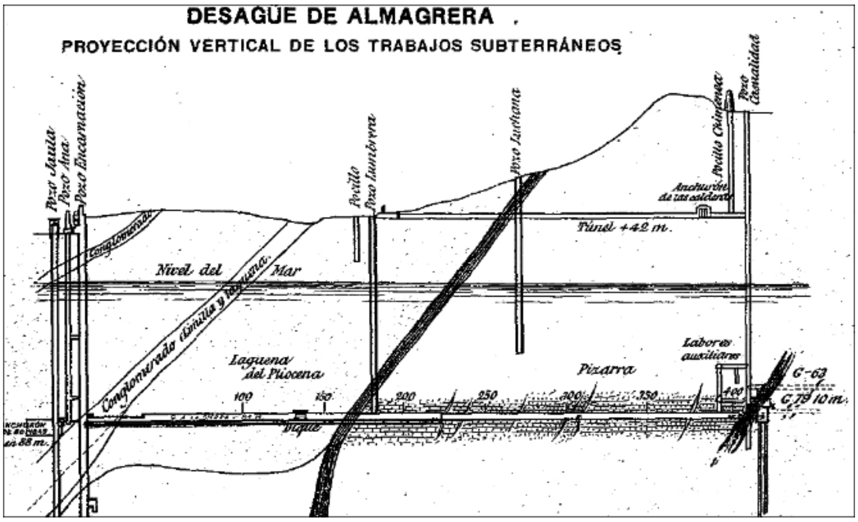
Although a new well had been sunk adjacent to the Portillo electricity substation in Las Rozas, the original well was only properly capped a few years ago after a tractor got a wheel stuck in it during ploughing.

Below left, the capped, old well and, right, the new well by the substation.

The drainage of the cold water was successful and everyone was pleased with the rate at which the water level was dropping. Then, there were problems. A collapse in a gallery at around 450 metres brought things to a halt.

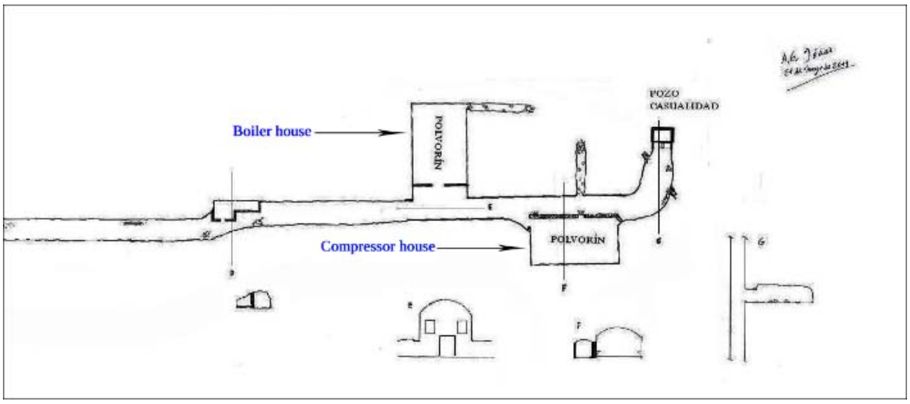
A costly stage two was about to begin.

In order to open a second gallery, at a slightly different angle, major works were required. A tunnel, 42 metres long, was driven from a point close to the original ventilation shaft, E, to link up with the shaft at Casualidad. At its end, two chambers were excavated, one to house boilers, the other, the compressors. A shaft was sunk to ventilate the area and Casualidad's shaft was extended down to the drainage gallery, where a further equipment chamber was excavated. Then, in order to deal with the increased volume of water flowing through this second gallery, a new pump needed to be installed in Encarnación.



Plan of the underground working.
Estadistica Minero 1908.

Plan of Casualidad's tunnel showing the Boiler and Compressor houses.
Drawing A G Jódar.



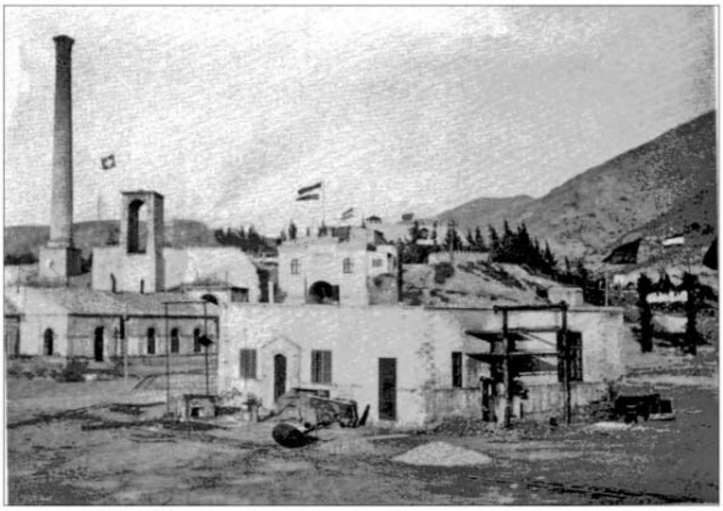
Left, Casualidad's main shaft.

Right, the ventilation shaft. The chimney was added C1903.

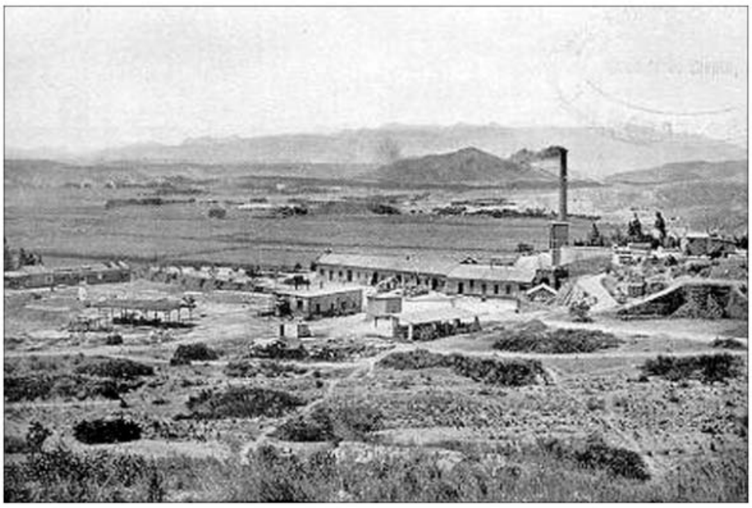
The tunnel entrance to Casualidad. The sloping wall on the right of the arch is the remains of one of the lime-kilns shown on Reinhold's plan on page 70.

These works were costly: the company was losing 15,000Pts a month and they tried, unsuccessfully, to raise more capital. They then tried to re-negotiate the terms of their contract and raise the levy from 16% to 25% but the mine-owners refused to agree to those demands. The upshot of all this was that, in 1903, the desagüe was taken over by a new company, the Compañia Minera é Industrial para España, with the mine-owners levy set at 21%.

So started the even more costly stage three of El Arteal's development.



El Arteal in the early days. The building in the centre under the Spanish flag is recognisable as Encarnación.
Un Siglo de Historia Minera. Bolea.



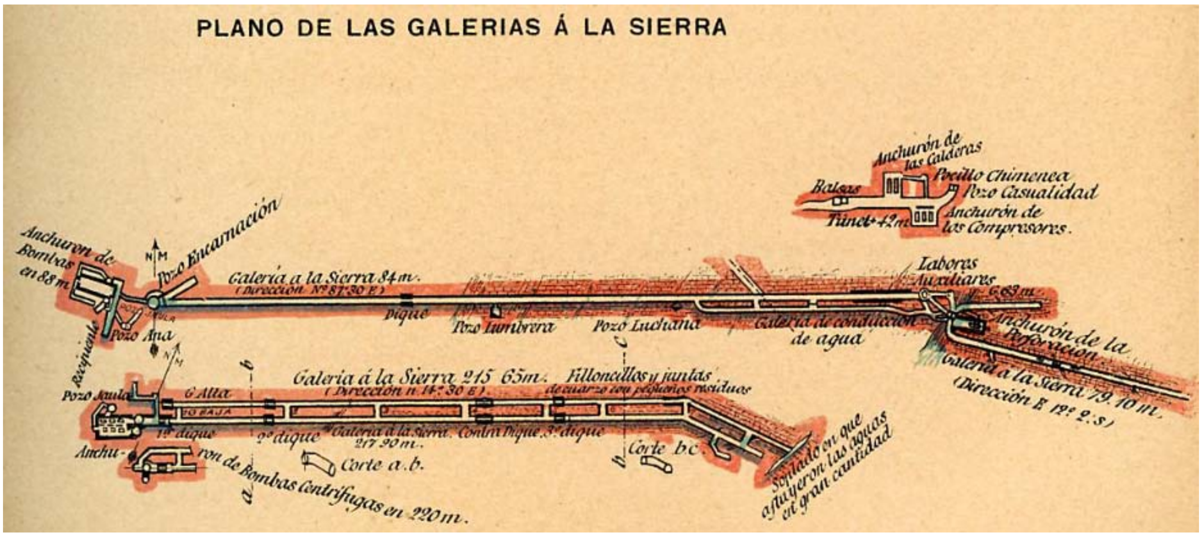
Another view.
Editions Martin.

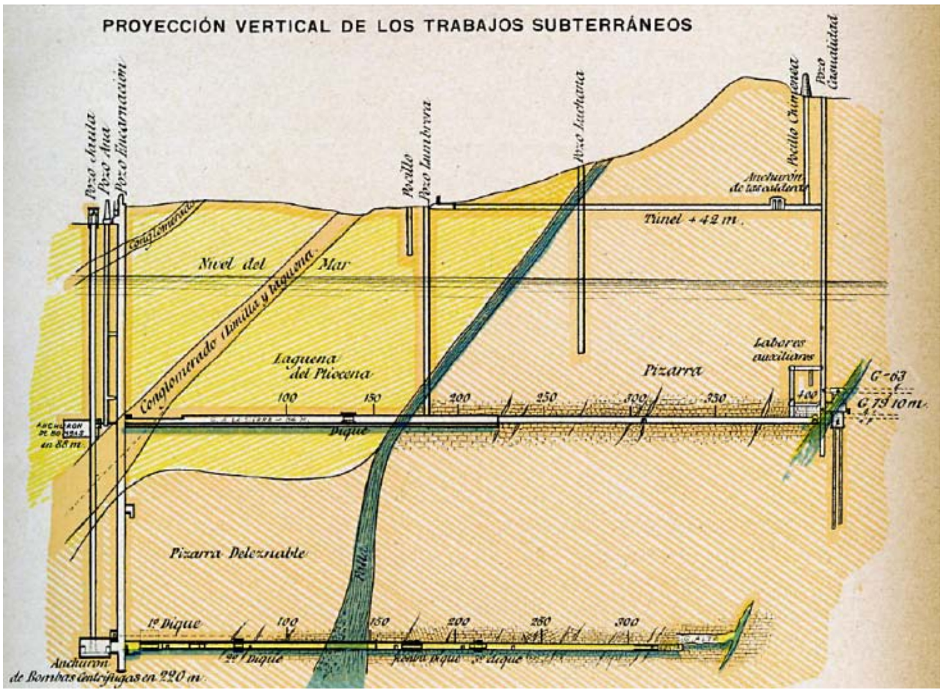
With the water level holding at 95 metres below sea level, and their contract requiring it to be lowered to 120 metres, this new company undertook a massive amplification of the installations.

The shafts, Encarnación, Jaula and Ana were taken down to 250m, 130m, and 132m respectively, below sea level and a chimney built over Ana to improve ventilation. A new plant room was excavated in the slate at 220 metres below sea level which comprised of an engine room and a pump house, both 18.60 metres long. Three vertical compound steam engines powered the three centrifugal pumps which operated at 1500 rpm. The inner parts of the pumps were coated with phosphor-bronze to protect them, as far as possible, from the corrosive nature of the thermal waters. The water deposit for the pumps had a capacity of 46,300 cubic metres.

Leading from Encarnación were two brick-lined water collection galleries, one above and slightly to the side of the other and at a vertical distance of 2.50 metres and a horizontal distance of 8 metres. The higher of the two was 300 metres long and the lower 332 metres. These two galleries were connected at intervals by incline shafts and both conduits were fitted with sluice gates. This arrangement allowed for the balancing of the flow of water into the reservoir and the pumps.

The 16th of March 1906 was a red-letter day, when the actual thermal waters were encountered as opposed to water which had accumulated in fissures.





Above. Plan of the galleries. The lower gallery met with the thermal waters of the Sierra at a depth of 220 metres and a distance of 332 metres from the pumping station.

Right. Cross section of the underground workings in 1906.

Both: Hastial Vol 2 2012.

This plan, for some reason, does not show the delivery shaft up which the water was pumped from the original conduit and pumps. ‘Estadística Minero 1908’ details how the other three shafts were lengthened, but makes no reference to the delivery shaft. In fact it states that the water was pumped to the surface via Pozo Jaula. This would mean that Jaula had cages, steam pipes and a rising water pipe, which seems rather odd. The other problem is that, without the delivery shaft and its ladder, the evacuation of the pump room in an emergency would have been difficult. The delivery shaft is still open and while Jaula has been capped and/or filled, and all that remains of it is the back wall. Another mystery! Wherever the water was pumped from, it ran down between the two walls at the back of the courtyard by the abandoned new-build and out through a grille set in the far wall. From here it was channelled along the top line of the field below, then behind the new pump house, along the line of the field wall and into the Rambla del Arteal. At some point, a flow metre measured the volume of water extracted. This was probably placed in the channel between the two walls.

Above. The water left the courtyard through the grille (highlighted).

Left. The pumped water flowed through the channel between the walls.

A new power plant was built in order to run the new machinery. Sited 80 metres from the old one, it was three times the size. The boiler room had two banks of four condensing boilers from which the superheated steam was channelled through triple insulated pipes, over to and then down, Pozo Jaula to the machines underground. The feed water for the boilers went through a very complicated purification process (of which more in Volume 3) and the draw was provided by a 45 metres high chimney. Luis Siret’s railway was extended to El Arteal in order to bring coke, from the port at Villaricos. The line was carried, from the Rambla de Muleria to the site, along a raised pier and an embankment, and then crossed a bridge over the road to the Sierra. The bridge supports are still, just about, standing. The coke was stored in a huge, covered purpose built store next to the boiler-house.

The remains of the bridge supports over the original track to the Sierra.

El Arteal after the new power plant was constructed.
F de Blain.

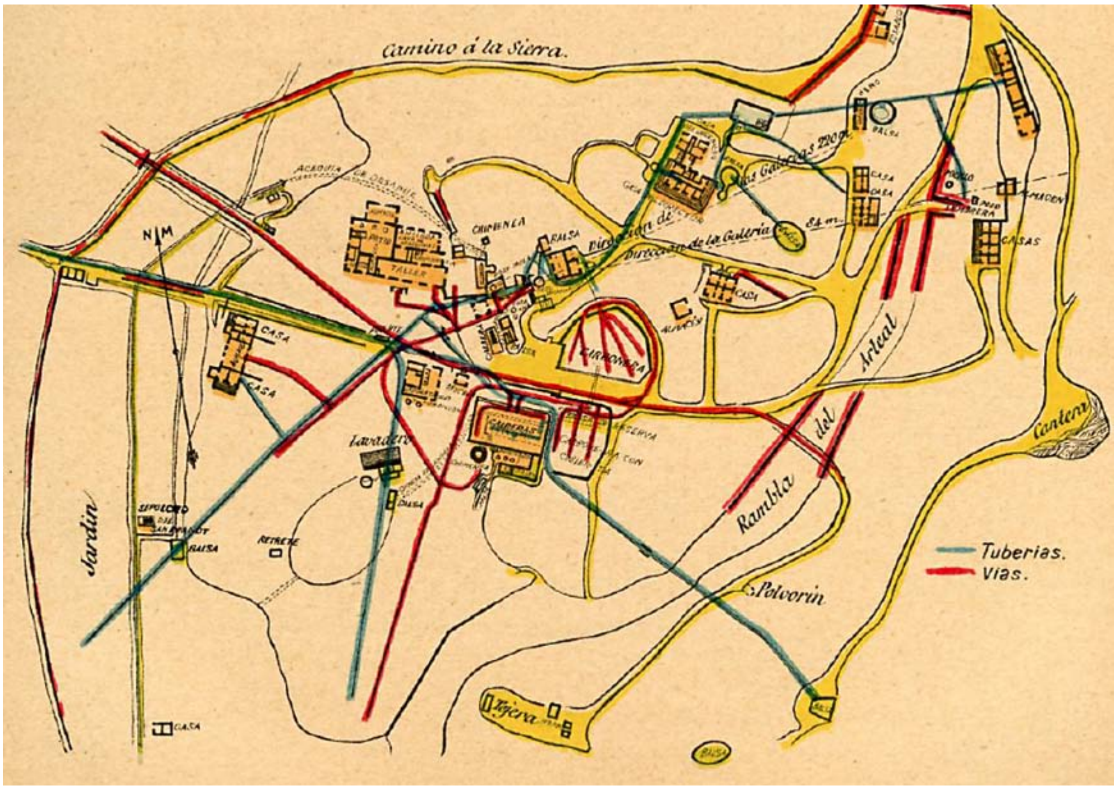
Above, general view of the power plant. The base of the chimney on the left is highlighted and the boiler room wall is behind the water tower.

Right, the base of the chimney, in front of the water tower.

The remains of the water tower. Tanks were situated on top of the tower.

Inside the water tower.

As well as these major works they installed a 10 horsepower motor to power a Schuckert dynamo to provide lighting for the site. Encarnación had lift cages fitted, and new motors were fitted for Jaula's lift cages. The forge, machine, and metal work shops were fully equipped with modern machinery, and there were two overhead cranes, one underground and the other on the surface.



Surface plan of el arteal in 1908. *Hastial 2012 after Estadística Minera 1908*

This detailed plan of El Arteal gives a very clear picture of how it was in 1908 and much of it remains to be seen today. However, everything that was in the area south of the power plant has disappeared apart from the balsas, or, water storage cisterns. The drain from the boilers of the new plant ran down to a lavadero, or ore washing shed, indicating that El Arteal was also the site of at least one working mine. The drain was then channelled past the retrete, or lavatories. Nearby, surrounded by a garden, was Alfredo Brandt's sepulchre. He had died in 1900 and, while his son Gustavo took over the business, it was his son-in-law Rafael Souvirón who, as the engineering director, was the company's driving force. On the south eastern side of the complex, was a tejera, or brick kiln, where the bricks used in the construction of the site were made, alongside the kiln were two ore furnaces. Of the polvorín, or dynamite store, there is no trace, but the cantera, or quarry can still be seen beside the top track.

The picture below shows the water tower and the wall of the boiler house, but as can be seen from the plan, the building which housed the calderas, or boilers was a considerable size. The adjacent covered carbonera, or coal bunker, was large, but the one over the road from it was even larger. The former was used as settlement tanks in later years, while the latter is currently covered by greenhouses.

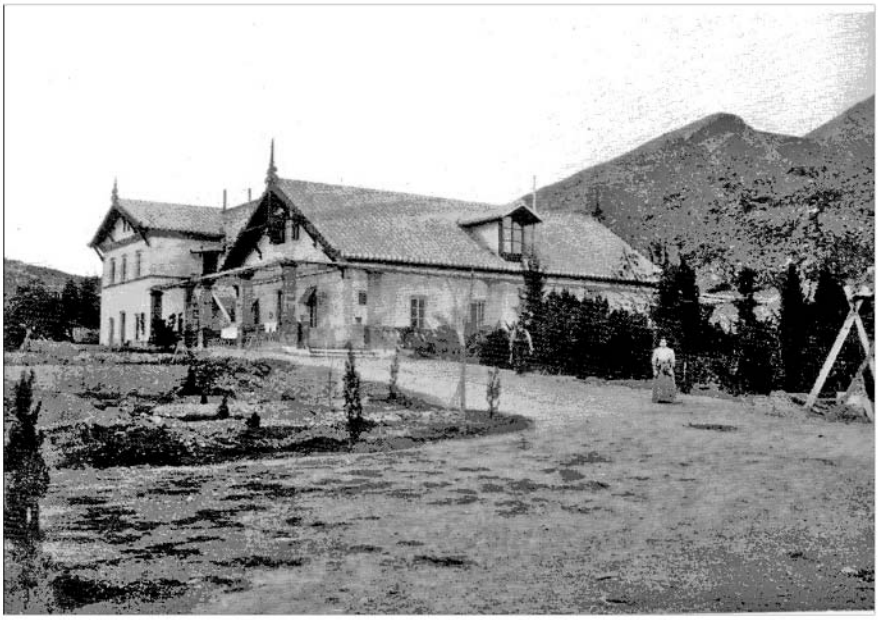
The view of the plant looking over the site of the covered coal yard.

The forge and metal shop were to the right of the boiler house along with the bascule, or weighbridge. The foundations of the workshop are still there, possibly because they are too substantial to be worth the bother of digging them out. Nearby is a large concrete block which I think was part of the weighbridge.

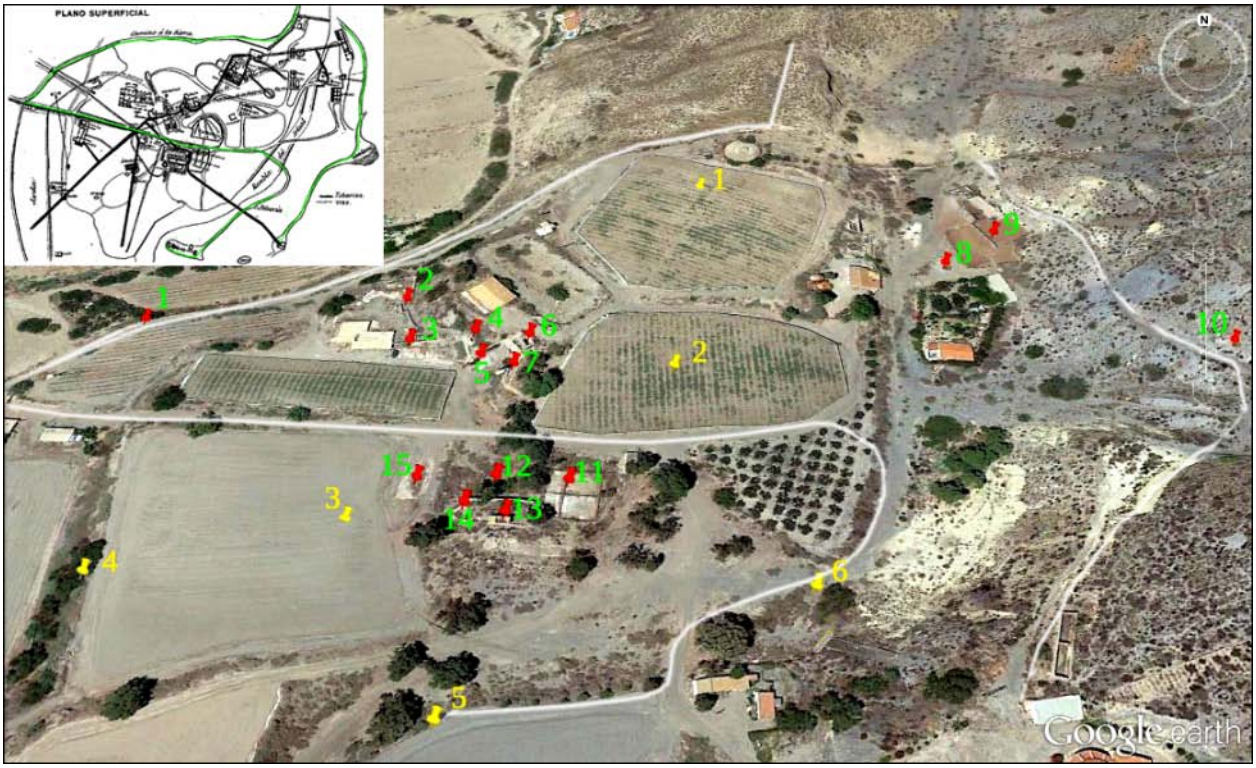
Looking out over the workshops.

The foundations of the workshops are in the foreground, then the chimney over Pozo Ana, with the building hosing Pozo Encarnación behind that. To the left can be seen the back wall of the arched building which housed Pozo Jaula. The base of the delivery shaft is to the left, and slightly above, Pozo Jaula. Originally, the delivery shaft had a tall open-sided tower over it. Of the original chimney there is no trace, I suspect that the Central de Transformación was built over it. The old boiler house is situated behind the greenhouse on the left. As can be seen in the 1908 plan, to the original boiler house was added a carpenter's workshop, a machine shop, a patio, or open work area, and a store room. An abandoned, unlicensed, half-built house stands where the patio and storeroom were.

The plant director and the engineer occupied chalets on the highest part of the site, the area is now covered by greenhouses. Luis Siret lived at El Arteal for a time. When his wife died, he moved with his children, into one of the two villas.



The director's and engineer's villas.
Un Siglo de Historia Minera Bolea.



El Arteal today showing the key locations from the 1908 plan.

Key.

Yellow Pins represent the 'Site of ...'

1. Director's and Engineer's houses
2. Coal bunkers.
3. Ore washing sheds.
4. Brandt's Sepulchre.
5. Ovens and brick kiln.
6. Dynamite store.

Red Pins represent the 'Remains of ...'

1. Railway bridge..
2. Drain.
3. Old boiler house and workshops.
4. Delivery shaft.
5. Jaula shaft.
6. Encarnación shaft.
7. Ana shaft.
8. Well shaft.
9. Ventilation shaft.
10. Quarry.
11. Covered coal store.
12. New boiler house.
13. Water tower.
14. Chimney.
15. Metalwork shop.

All of these improvements to the infrastructure were very successful. The water level was reduced to 127 m below sea level, even in the Barranco del Jaroso. New mining companies were formed and exploitation recommenced. The whole area was revitalized, however, the new boom was short lived. El Arteal was the largest civil works ever seen in Spain, but it was also the most costly. The fall in the value of the extracted minerals meant a fall in income in real terms for the project. This, coupled with increasingly high maintenance costs, forced the Compagnie Minière et Industrielle pour L'Espagne to shut the machines down in 1912. The old story of money down the drain and inundated mines.

After 1912, the Desagüe had a rather chequered history. In 1916 a company by the name of Desagüe de Almagrera S.A. took it on and decided to use coal rather than coke as fuel for the boilers. Needless to say, that was a disaster, since the boilers were designed to be run on coke. They then tried to negotiate a contract with a hydroelectric company in Júcar, but that came to nothing. Finally, they installed a diesel generator to pump water out of the flooded pump room, and then managed to get one of the centrifugal pumps operational. This was not enough to prevent the water level from rising and pumping ceased in 1921.

The situation in the Sierra was poor, the lead and silver mines were dying a slow death. Meanwhile however, in Las Rozas, the extraction of iron ore was booming. Luis Siret and his Société Minière d'Almagrera was a dominant player. He was also extracting iron ore in the Sierra from República Romana, Boletín and Remedios, so he had an interest in maintaining de-watering. In 1924 he took over the running of the desagüe. He improved the electricity supply to the main engines with 26,000 volt hydroelectric power, supplied from Bayarque 80km away. As this supply tended to be erratic he built the Central de Transformación which housed a 535 horsepower German diesel engine. To the three pumps already installed, he added a fourth, two of which were powered by the power generated on site, and the other two by the power from Bayarque. With a constant source of power the de-watering was successful. For the mine owners the benefits did not last, as, in 1929, the Société Minière d'Almagrera moved their operations to North Africa and the running of El Arteal again changed hands.

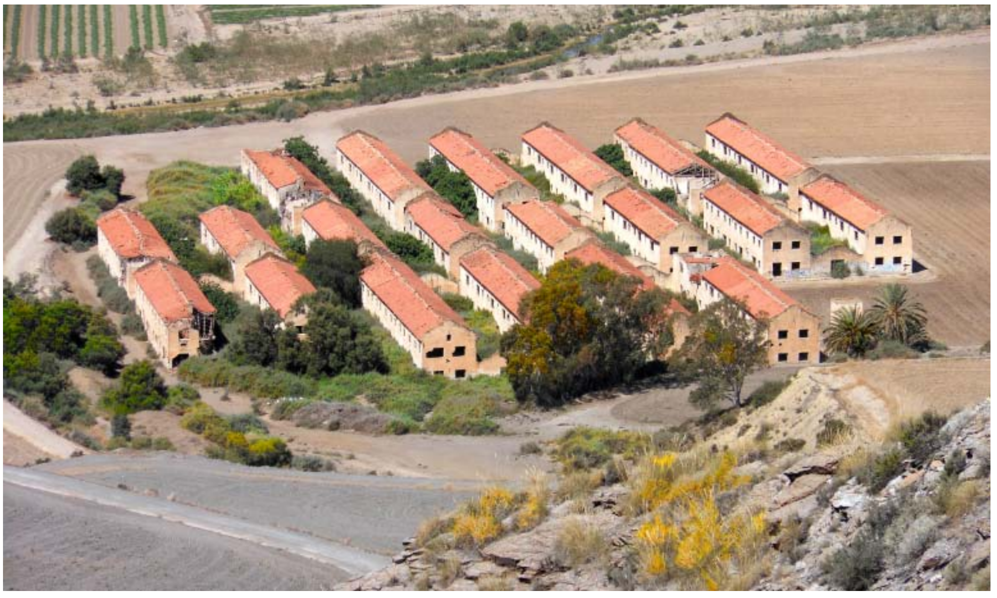
The Consorcio de Almagrera S.A. then took over the running until 1933. They broke their contract with the company supplying them with hydroelectric power and built a generating plant in Villaricos, powered by a diesel engine. This proved to be inadequate and the mines were again flooded.

Next up were Empresas Eléctricas e Industriales who used both the plant at El Arteal and that at Villaricos, enabling some of the mines to recommence activities. They improved the Villaricos generating plant by installing a new alternator, a 1200 horse-power MAN engine and improved the cooling system by piping in filtered sea water. The future of the remaining mines seemed to have been secured, but then the storm clouds gathered and the whole country was engulfed in conflict. The upheaval and uncertainty of the civil war made the efficient operating of the plant impossible. Fuel shortages meant that the electricity supply from Villaricos was erratic and, eventually, pumping and all other activity ceased.

Once again the mines were flooded.

The end of an Era!

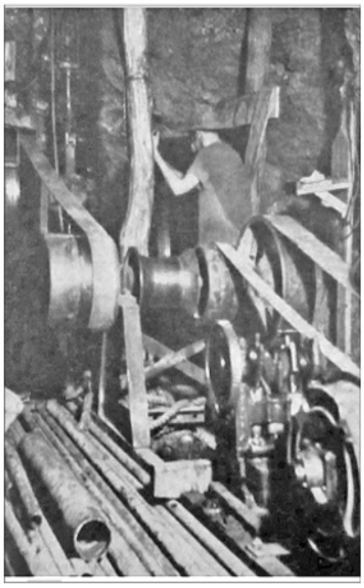
Chapter 5. The Renaissance of El Arteal



Following the Civil War, one of Franco's initiatives was to recommence mining activities in the Sierra Almagrera and, in 1945, Minas de Almagrera was formed. Franco's aim was to promote a “home grown” industry rather than one reliant on foreign investment for the supply of lead for both the domestic and the export market. So began a second phase of activity at El Arteal far greater than the first, but of which there is virtually no trace.

Minas de Almagrera Share Certificate.

Minas de Almagrera concentrated their attention on the more important mines. (At the time only nine were still active.) They took over the desagüe, the railway, the electricity generating plant and the loading pier in Villaricos. Since 1935 only the superficial water had been drained and the water level in the mines was just 80 metres below sea level. In order to start production, the water would first need to be lowered to at least 160 metres. New pumps were installed in Encarnación capable of lifting 40 litres per second to a height of 250 metres. These began pumping in 1949. Then, in 1952, new plant was installed at a depth of 320 metres. The desagüe was back in business! (The shaft of Encarnación is as deep as the Sierra is high.)



Installing the pumps in Encarnación.
Minas de Almagrera S.A. Sánchez Picón.

New technology was introduced and a modern ore processing plant was constructed. As well as tanks and warehouses for the concentrates, a factory was built to manufacture the sodium ethyl xanthate needed for the new floatation separation process. Water tanks and purifiers were installed.

Froth flotation at El Arteal. *Helios.*

They converted the room which housed the compressor for the cold water drainage pumps, situated below Casualidad, into a “polvorín” or explosives store.

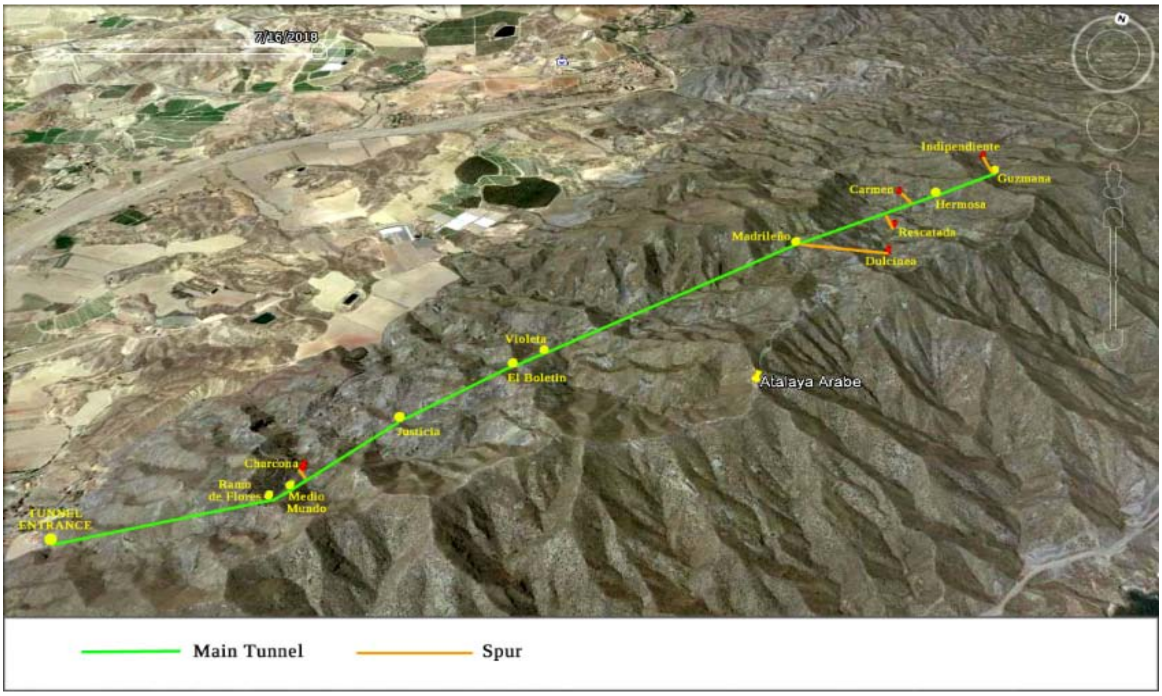
Entrance to the polvorín. *Start of the tunnel leading to the site of the compressors.*

Inside the polvorín. *mti blog.*

200 apartments for married personnel, and two accommodation blocks for a further 200 workers were constructed, together with bath houses, medical facilities, offices and management buildings. A total of 615 personnel were employed on the site. It is interesting to note that as well as the workers physical well-being MASA was required to look after their spiritual needs.

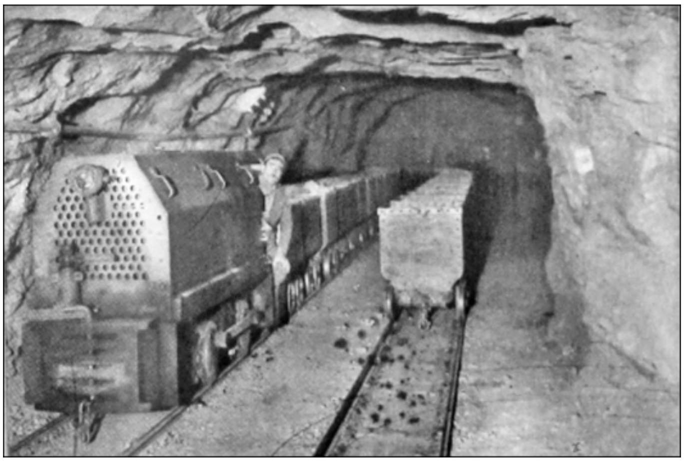
Above, the married quarters and right, the single quarters. *Minas de Almagrera S.A. Sánchez Picón.*

Minas de Almagrera turned their attention to the small socavón in the Barranco Las Palomas. Rather than access the mines via the donkey tracks up the mountains they decided to access them directly through the mountain. The original tunnel was 700 metres long and 54 metres above sea level. It was widened, lowered and extended to link 99 mines. By 1952 this number had increased to 136.



The tunnel ran to Ramo de Flores, then to Justicia (Casta Diva) via the Medio Mundo with a spur to Chacona. From Justicia it ran to El Boletín and Violeta, then through to the Madrileño. From Madrileño the main tunnel continued to Hermosa with a branch looping round Dulcinea and spurs to Rescatada and Carmen. The last section was from Hermosa to La Guzmana which it circled, with a spur to Independiente. The purpose of this mammoth undertaking was to provide a means of transporting ore from the 136 mines to the washing and recuperation plant at El Arteal. Within the tunnel 4 diesel locomotives and 400 wagons, some of which were adapted to carry personnel, ran on a double track railway.

A diesel locomotive operating inside the tunnel.
Minas de Almagrera S.A.Sánchez Picón.



By 1951 the main tunnel was 4,123 metres long, with a further 1,130 metres of branch line. It was re-christened Santa Barbara, after the patron saint of miners, and was in use until 1958 when MASA's operations ceased at El Arteal.

For the train-spotters. While researching this project I unearthed some details of the diesel locomotives used at El Arteal. They were built in Germany in the Ruhrtaler engineering works by Schwartz & Dyckerhoff.

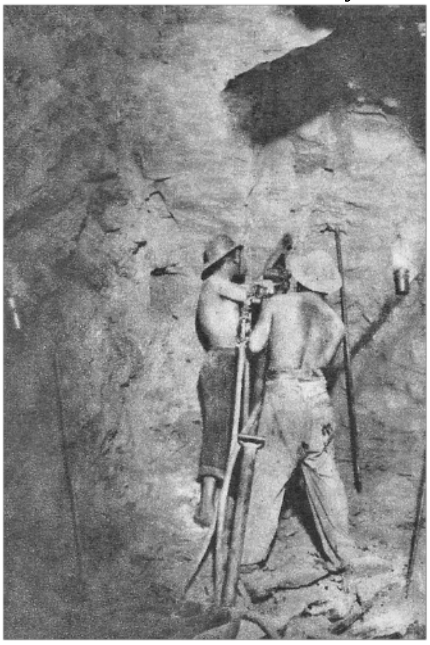
Manufacturer's #	Date	Model.
2907	19/05/1951	G-22
2937	26/10/1951	G-30
2938	26/10/1951	G-30
2939	26/10/1951	G-30

I haven't been able to determine whether they were ever "named".

The grand opening of the Santa Barbara tunnel on 22nd August 1951.
Minas de Almagrera S.A. Sánchez Picón.

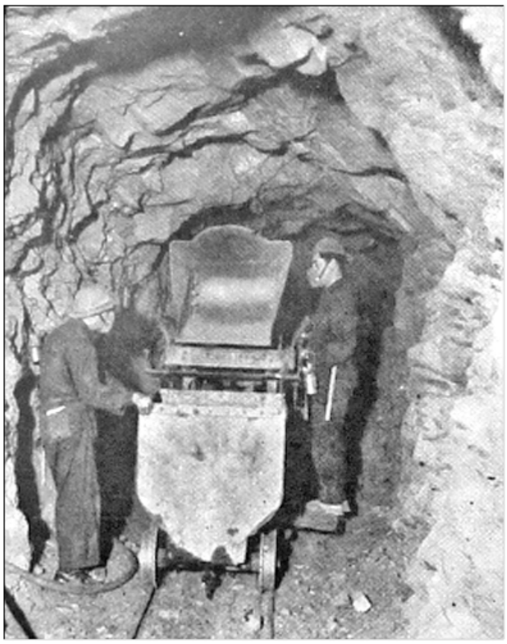
A later photograph of a group of miners at the entrance to the tunnel. (with a nod and a wink to Health & Safety practice!)

In 2011the tunnel collapsed some 400 metres from the entrance and is now impassable. The earthquake in Lorca was in 2011 and the shock waves were certainly felt in El Arteal so it is possible that the collapse was a result of this seismic activity.



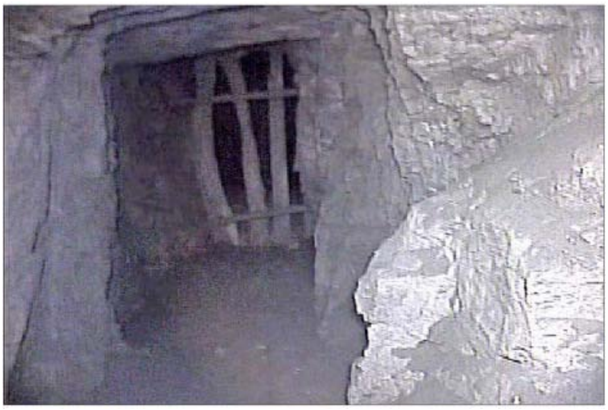
Miners working in the Santa Barbara tunnel.

Minas de Almagrera S.A. Sánchez Picón.



The entrance to the Santa Barbara tunnel.

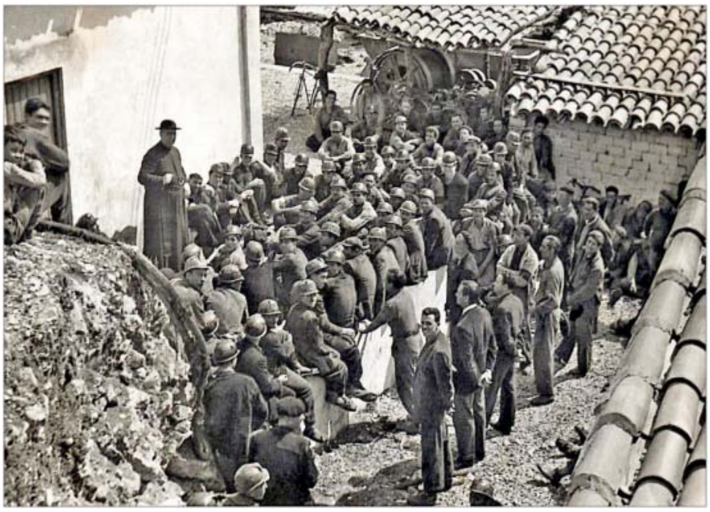
Just inside the tunnel. *mti blog.*



A collapse within the tunnel.
Photos A G Jódar.

The entrance to the Santa Barbara tunnel from a gallery in the Mina Violeta.

Manpower was a problem for MASA. The single and married miners' quarters were necessary because they had to recruit experienced miners internationally. The local expertise had drained away after massive emigration between 1910 and 1940, due to the closure of the mines and foundries and the effects of the Civil War. The population of Cuevas in 1910 was 26,000 but by 1940 it had dwindled to 10,000. (in 2016 the figure was 13,362). Some of the recruited miners were Welsh. One can only wonder what they, as Presbyterians, thought of the enforced Catholic "pastoral care".



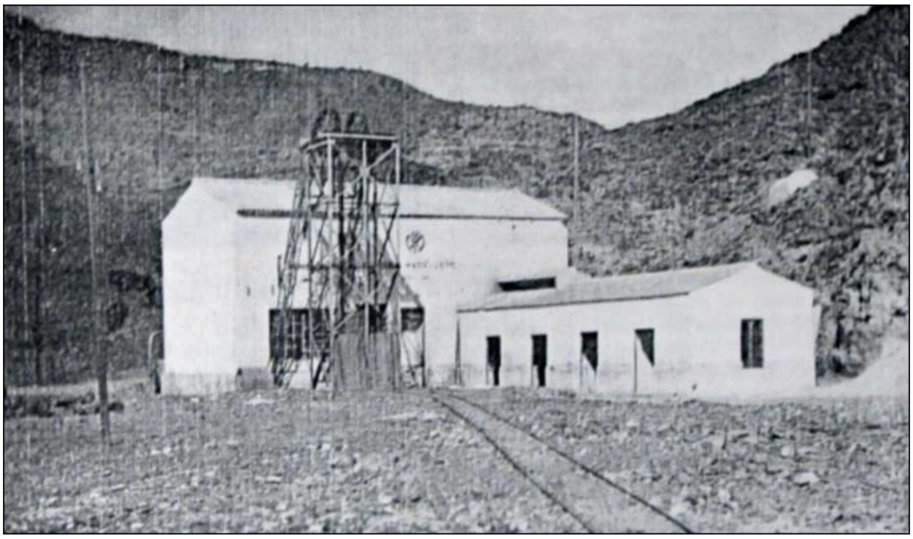
Pastoral care like this at the Andorrana mine in Aragon was a requirement.

In 1956, manual workers received a 23% pay rise, mandated by the government. In the light of this, MASA carried out a feasibility study on all of the workings covered by the company. With the seams either worked out, or of poor quality, El Arteal was found to be uneconomic. In 1957 mining ceased and work was concentrated on just recuperating ore from the waste of various mines, using the modern techniques.
The price of lead on the international market was declining and the home market was shrinking as safer alternatives to lead were gaining prominence. The cost of energy was crippling. Even with the generating plant at Villaricos with its 1500hp motor and the one at EL Arteal with its 350hp Benz diesel, the process was still reliant on the El Chorro hydroelectric station for additional power.

In 1958 everything was dismantled. El Arteal was dead.

MASA had seriously overestimated the exploitable reserves both in terms of quantity and quality. They had assumed that the ore bearing seams continued below the level of previously drained workings. Unfortunately, they tended to peter out, or, were of poor yield. Most of the production was from the scavenging of spoil heaps. It is possible that the system for this operation was a kind of reverse mining, where material was taken from the tips, down into the mines and then transported to El Arteal via the Santa Barbara tunnel. The main shaft of the principle mines along the tunnel route were updated. Justicia immediately strikes you as being a modernised shaft, whereas externally, Ramo de Flores only shows signs of repair to the mortar of the castilletes, although a lot work was done below ground. By contrast, Madrileño looks as ruined today as any other mine in the Sierra after its new head frame was dismantled. (It had never had castilletes.)

Above, mina Justicia (Casta Diva). Right, the shaft.



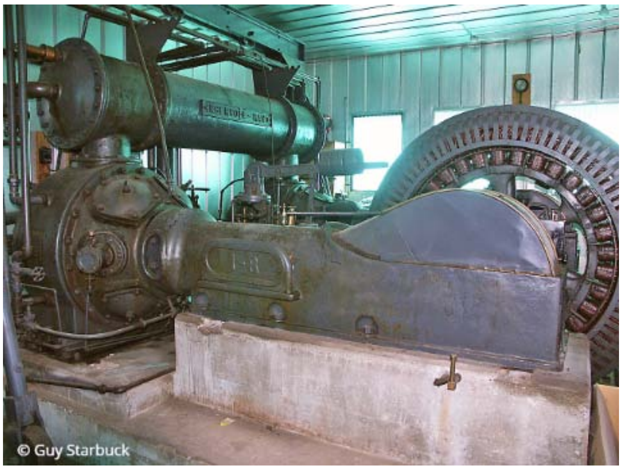
Madrileño in the 1950's
Minas de Almagrera S.A.
Sánchez Picón

Madrileño today.

The arch at Hermosa had fascinated me for a long time. All I knew about it was that it had been constructed by MASA and that it was not a tunnel, nor was there a shaft in it. I had not been able to work out a safe way to reach the entrance and so could only look and wonder. Señor Jódar took pity on me and guided me over the spoil heaps to the door. What a surprise awaited me!

It was the housing for the air compressors used in the Santa Barbara Tunnel. Adjacent to it is the electricity transformer that brought the power to operate them. It stands just two or three metres from the ruins of the first transformer in the Sierra erected in 1903.


Inside Hermosa's arch.



Air compressor similar to those that would have been housed in Hermosa.

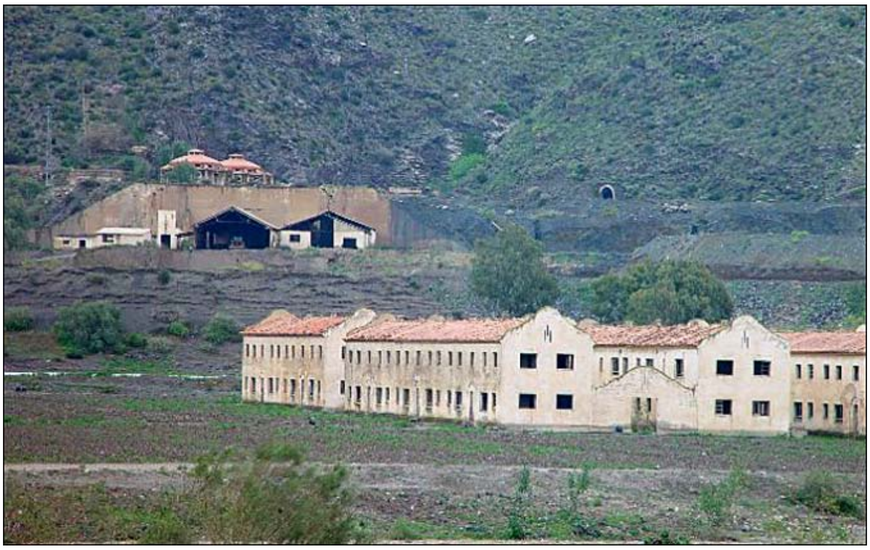
The transformer building.

Archway at the end of the siding from the Santa Barbara tunnel that led into ...

… this arched area.

Next to the entrance to the Santa Barbara Tunnel is what looks like a railway siding that leads to a small archway that, in turn, has an arched exit at 90º to the entrance. I am now wondering if this was also a compressor housing.

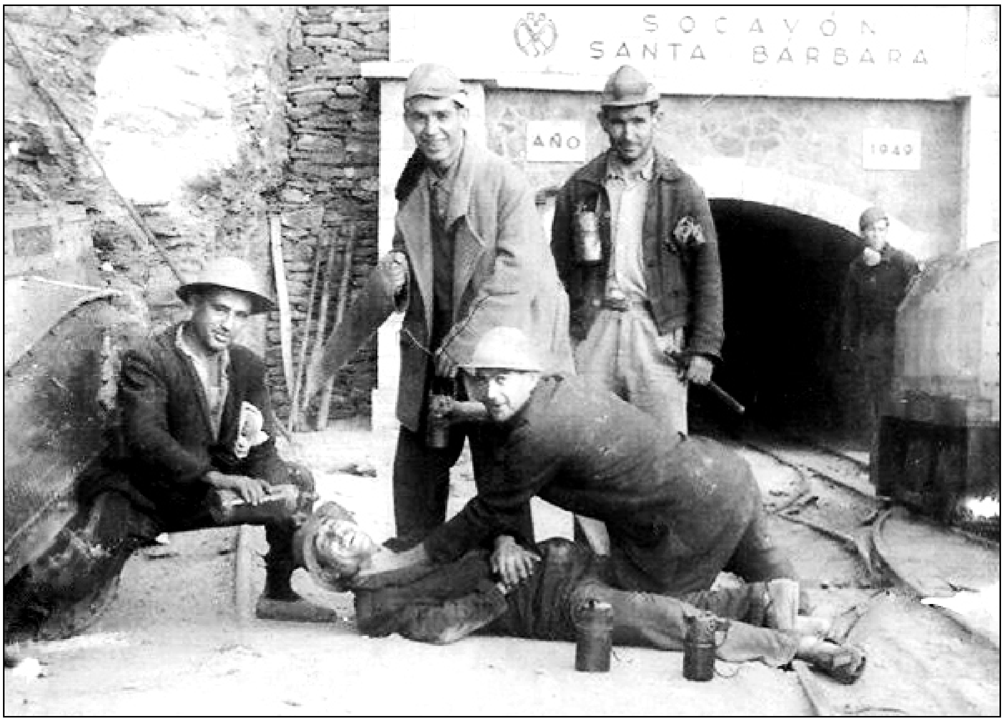
In the 1980's, a now defunct Spanish company, Peñarrolla, reopened the Santa Barbara tunnel with a view to extracting Lithium, which is present in significant amounts in the thermal waters. Unfortunately, this initiative came to nothing but, with the rise in value of Lithium, the prospect of reactivation of exploitation of the area should not be dismissed.



View of lavadero below the bathhouses. *Peter Craven.*

The bathhouses are now private apartments and, until a few years ago, the ruins of the miners' quarters were used by the emergency services and the military for training exercises. The old ore processing sheds are used as storehouses. The rest is now put to agricultural use. A sad end for such an important and interesting site. On a more positive note, because the later exploitations were carried out almost entirely from underground, the remains of the mines are still in the mountains and the donkey tracks continue to lead you to them. Ghostly, almost mystical remnants of that bygone age are there for both the casual and the more inquisitive visitor.

Chapter 6. Life, Times and Technology.
El Arteal from 1945 to 1991.



6.1. Introduction.

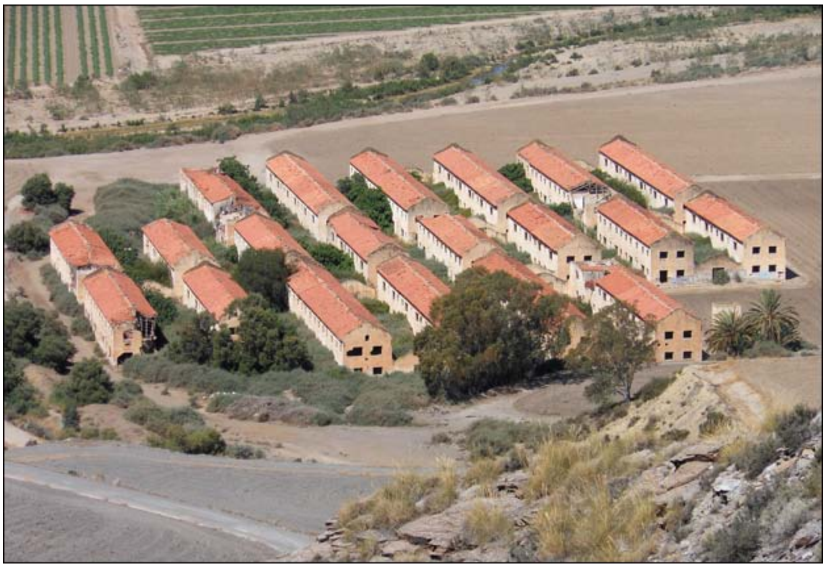
Information about MASA's time at El Arteal has been difficult to find. There is more information about the period leading up to the Spanish Civil War than there is after it. Rodrigo's photographs and contemporary accounts that have been digitized give a vivid picture of the late 1800s. Moran's series of postcards, produced for Luis Siret's company, and visitors' accounts do the same for the early 1900s. In contract, 1936 to 1975 is a bit of a black-hole and few photographs or accounts have found their way to publishers or websites. Hopefully, the recent upsurge in interest by younger Spaniards in their recent history, and their refusal to continue subscribing to the collective amnesia about the period, will result in more information becoming available. In the case of the mines of the Almagrera it is becoming critical as their history, literally, crumbles to dust and their echos are blown away on the wind.

6.2. The miners' quarters.

One of the photographs that did catch my eye was this one of the married workers' accommodation block under construction.

Minas de Almagrera S.A. 1944-58. A S Picón & I G Jiminéz.

The married miners' housing complex was called La Corea as in the country Korea. Whether this was for ideological reasons or not I don't know. The bunk houses for the single men were situated in the area above and behind the married quarters.



The remains of the Miners' Quarters.

The last unit of the first block by the electrical transformer was used as a board school for the employees' children. There were no structural changes made to these units. There used to be the wrought iron legend "Escuelas" above the door. Nowadays you would never know that a school had been there. The ironwork was stolen during the recent economic crisis.

Left, the board school complete with legend and right, the more recent view.
.

A gentleman by the name of Higinio Robles Campos lived at El Arteal from 1954 to 1962 and attended the school. In the photograph below, taken in 1954, the gentleman on the motorbike in Guardia Civil uniform is his father.

El Padre de Higinio Robles Campos.
Collection: The Robles Campos Family.

What was the relationship between the Guardia and MASA? Was Franco worried about communist sympathies amongst the various nationalities of the miners? Whatever, Señor Campos seems very happy with his lot.

6.3. The hospital.

Two of the housing units in the accommodation block were modified to form a trauma clinic. These are situated at the western end of Calle C. The fireplace has been removed from the right hand unit and the walls tiled. It served as an operating theatre. From here, a doorway leads to two recovery wards. The left hand unit has also been modified, in this case the sink has been enclosed for some reason. The next room, painted black, was the X-ray room.

Operating theatre.

Recovery wards.

Left, the x-ray room. Above, what was possibly a waiting room or dispensary. The sink in the left hand unit was enclosed in a cupboard.

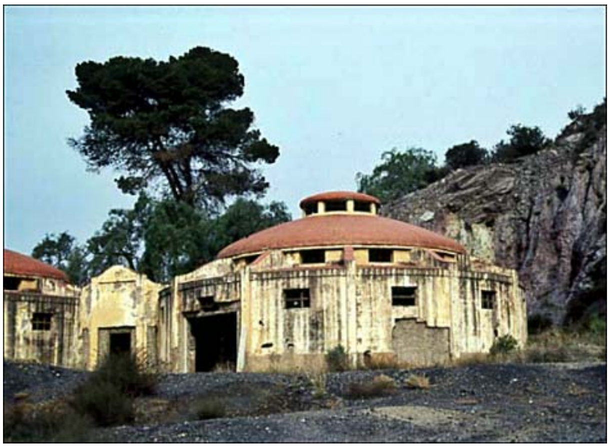
The doctor's house was by the two white towers in this picture.

6.4. Amor más allá de tiempo, en El Arteal. (Love ever after, in El Arteal.)
This web post is a charming account of life in these quarters by a lady by the name of Maribel who lived there and worked in the hospital as a young girl. By young, we are talking, from the age of 12. As she herself says, "at that time there was no age to work". The "love ever after" tag line refers to a touching tale of love letters exchanged along the washing line between two blocks, of parental disapproval, of the intervention of the local curate, of a begrudgingly allowed midnight wedding in Las Herrerías, and most of all, of a lifetime of happiness with her beloved Paco. As well as being a love story, Maribel's account gives some insight into life at El Arteal. Señor Campos wasn't the only person happy with his lot. She describes it as a good life and a good place to live. Full time employment, a bar, a football pitch, two cinemas, 250 kilos of coal a month for the range, electricity, running water on tap and an indoor flush toilet. More than could be said for housing in Las Herrerías or La Muleria. Maribel was content with her lot. Not a life full of luxuries, but not wanting for much either. In the days when you could still walk in the courtyards between the blocks, I always sensed that they had been happy places, where women had hung out the washing, gossiped and shelled peas. A place where children had played and where love had blossomed. Now I know that I was not mistaken. Such a shame that they are going to rack and ruin! Maribel recounts that there were three main groups at El Arteal, the British, the Germans and the Spanish. She asserts that the British and the Germans left everything in good order and that it was the Spanish who, for some reason, trashed the apartments. Looking at the systematic destruction of the bathrooms and sculleries, I don't think that it was done by the ordinary Spanish: I believe that it was a measure, possibly ordered at company level, to prevent squatters from occupying the blocks.

Maribel's Paco worked in the offices which were near to the workshops. Paco always said that the youngsters who were trained there left with good skills. Where the offices and workshops were I don't know. I suspect that MASA used the old workshops that were already on site since they would have been already equipped with lathes and forges etc.. The offices could well have been in front of Encarnación by the abandoned new build.

6.5. The bath houses.
A measure of how much of a show piece El Arteal was are the bath houses. The normal pit bath-house of the era were the basic showers and locker-rooms like those at the Mina Andorrana in Teruel, Aragon. In stark contrast, the bath houses at El Arteal are something else! The twin, circular edifices could win a design award today. The present landowner has recently refurbished them and converted them into two luxury apartments, restoring them to their original glory.

The spartan showers and changing room of the bathhouses of the mine Andorrana. A. Pizarro.



The El Arteal bathhouses, left in 1999 (Gonzalo Garcia) and right, after renovation (Panoramio).

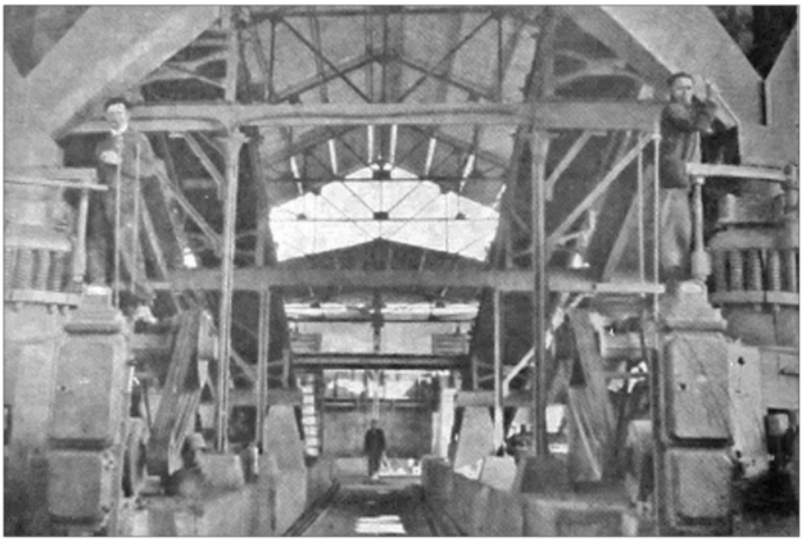
We also have the same landowner to thank for the conversion of the substation and the old MASA buildings next to the sheds, into housing for field workers.

6.6. Ore processing at El Arteal. Froth flotation, las aguas salas, ball mills and spiral classifiers.
MASA's lavadero was a proper ore mill, with all of the most modern technology and equipment. A far cry from the days of the criba cartagenera and the donkey-powered cone mills. The wagons bringing ore out of the tunnel tipped into hoppers in the area between the bath-houses and what is now a retaining wall. (The area has been filled in and levelled.)

Left, screenshot of the bath houses and sheds in 2002 showing the mouths of the hoppers at the top of the wall.

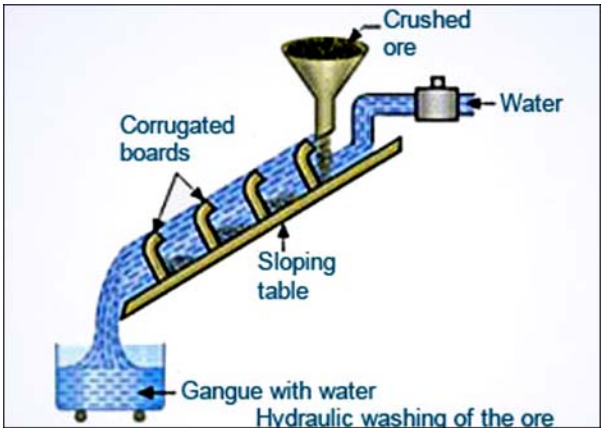
Right, the lavadero retaining wall.

The main processing was carried out in the two sheds which is now used for storage.



Inside the shorter of the two sheds.
Minas de Almagrera S. A. Sánchez Picón

As far as I can work out this shed, the shorter of the two and with the split-level roof, held a pair of gravity washers which separated the heavier, ore-bearing material from any organic debris and lighter matter. The heavier material gathered in the corrugations while the waste was carried down to the bottom. Vibrating tables are a possibility, but the angle of the ramps are really too acute for this method of separation.



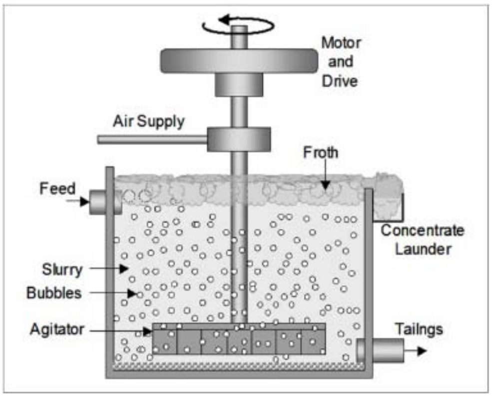
Gravity washer diagram.

It is probable that the second shed housed ball-mills and the froth floatation tanks.

Froth floatation.
The development of froth floatation enabled the economic recovery of valuable metals from much lower grades of ore, and previously considered waste material. It enabled MASA's main operation, that of, scavenging the spoil heaps left from previous activities to be carried out.

The process selectively separates hydrophobic (non-wettable) from hydrophilic (wettable) materials. The difference in hydrobicity between the waste gangue and the valuable mineral is increased by the use of surfactants. (Compounds that lower the inter-facial tensions between a liquid and a solid, e.g. detergent).

Here, at El Arteal, the galena was made more hydrophobic by the addition of sodium ethyl xanthate as a surfactant. The pulp, consisting of wettable and non-wettable particles, was then introduced into floatation cells or tanks and aerated to produce bubbles. The non-wettable particles attached themselves to the bubbles which rose to the surface forming the froth that gives this process its name. The minerals that did not float were scavenged, subjected to further floatation, in order to glean any remaining valuable particles. The froth, containing the valuable ore was removed, washed and dried.



Cross-section of a flotation cell

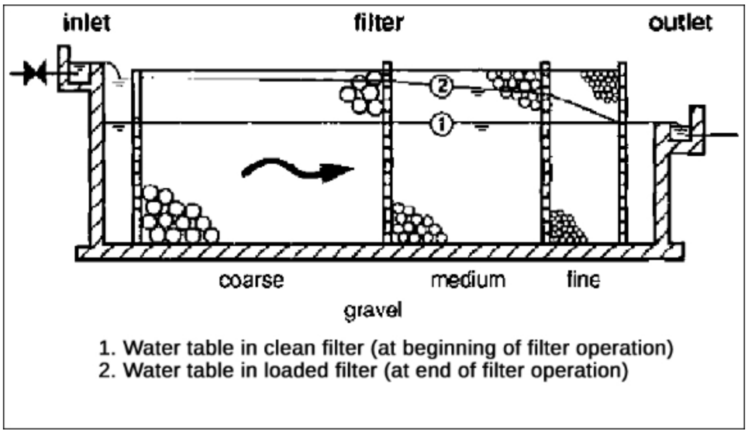
Ore-laden froth

Las Aguas Salas. The locals use this term for the gravity separation tanks which are beside the track leading up El Arteal. These tanks are a bit of a mystery. I know that the water storage tanks and the coal bunkers for the old boiler house were sited here. I have a feeling that these were simply modified to act as gravity tanks when electric power was installed and they became redundant. I don't doubt that MASA used them, but I think that they simply "made use" of them.

They are quite a distance from the main recuperation and washing plant. There was possibly a gravity fed pipe line from the sheds to the tanks. It looks as if the water was supplied from either, the pumped outfall of the desagüe, or the old water deposit by the Central de Transformación. They could have been used to scavenge particles of ore in order to reprocess them.

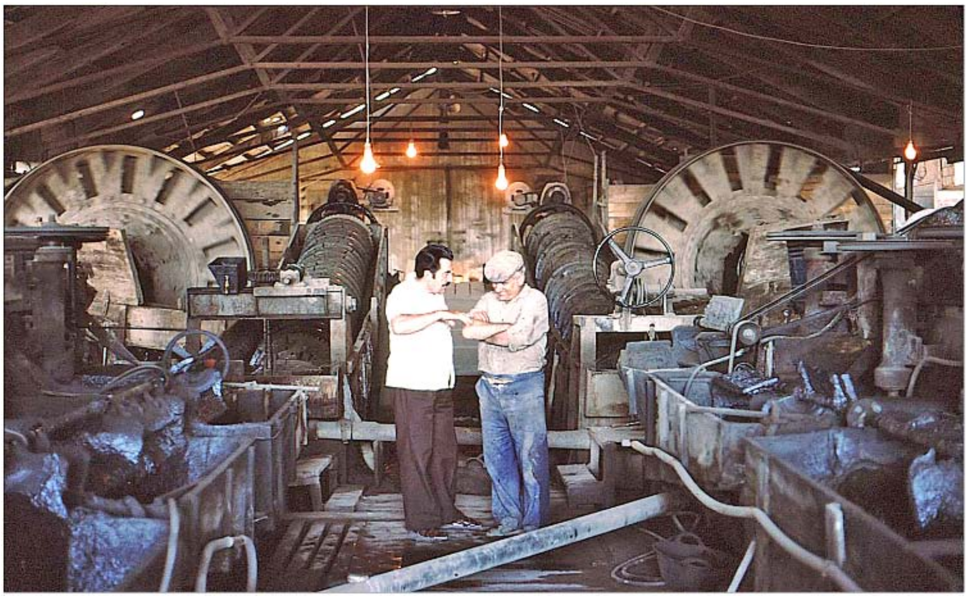
Settlement tanks at El Arteal.

Settlement tank diagram.



After MASA pulled out of El Arteal in 1958 a private company refurbished the ore mill and continued to recuperate material from the spoil tips, particularly those in the Jaroso valley, until as late as 1991.

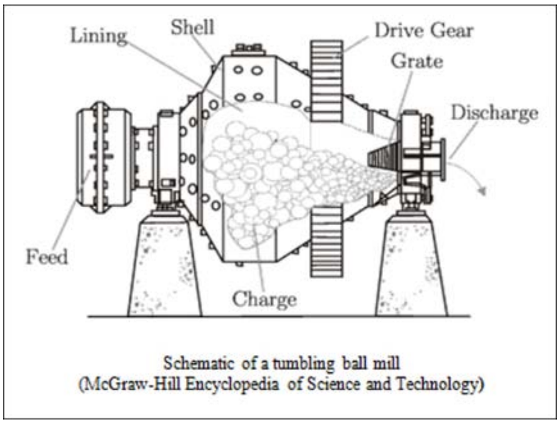
This superb photograph from ‘el blog de helios’ of the interior of the other shed is from that period.



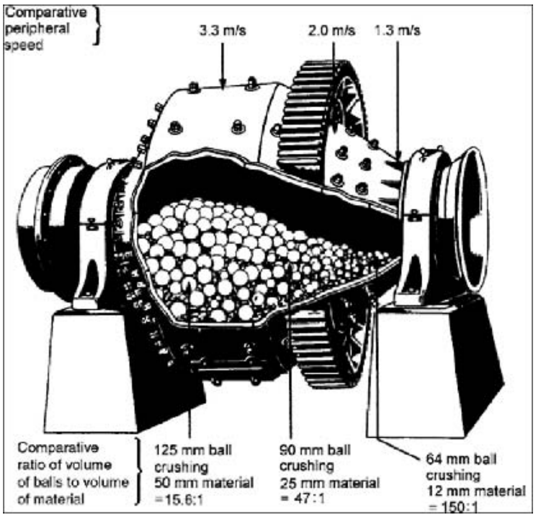
Ore processing at El Arteal.
Helios.

The large wheels on either side of the photograph are the ends of two massive ball mills and what looks like a pair of Archimedes screws are spiral classifiers. The containers full of evil looking bubbles are froth floatation tanks.

Ball mills.
The ball mills crushed the ore bearing material, preparing it for further processing. They are rather simple, but effective devices, which have changed little in the intervening years. The two profile diagrams show how ingenious they are. The shape of the internal drum means that differences exist in the rotational speed along its length. This effects the distribution of the various sizes of balls with the result of drawing the finer ground material towards the discharge port. From here they are transferred to the adjacent spiral classifier.
Ball mills were extremely expensive to operate and used vast amounts of electricity.

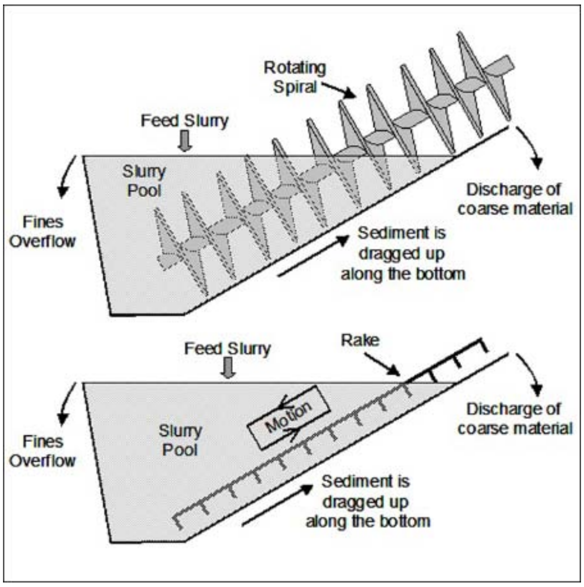


Schematic of a tumbling ball mill
(McGraw-Hill Encyclopedia of Science and Technology)



Above & right, Ball Mill profiles.

Spiral classifier.
Spiral classifiers work on the principle that solid particles with different sizes and proportions have different falling speeds in liquids. Particles small and uniform enough to go onto the next stage are passed on to the floatation tanks. Coarser particles are carried up by the action of the Archimedes screw and returned to the ball mill for reprocessing.



Spiral classifiers diagram.

6.7. Another of life's mysteries.

The mystery structure.

This structure, situated below the processing sheds, intrigued me. I think that it was originally circular, and that the bit behind this wall has been either in-filled or destroyed. When I was looking again at the picture of Señor Robles on his motor bike I noticed what was in the background.

Detail from Señor Robles photo.

My mystery structure is the remains of a circular, raised tank. The level of the land has been raised when the area was put to agricultural use, so the supports for the tank are probably rotting away underground. So what was it? The most likely explanation is that it is a settlement tank, but not necessarily for galena. It looks like the tanks used for the settlement of iron ore, like the modern version below.

MASA had taken over the iron ore calcination ovens in Las Rozas, so were probably processing spoil from there. However, a chance meeting and conversation with an elderly gentleman in the mountains confirmed my theory about the circular tank. This gentleman told me that his uncle used to drive a truck taking iron-rich waste from the spoil tips of the mine La Guzmana. His uncle had described the spoil being fed into a large circular tank where it was stirred. Obviously, at the time, the track to La Guzmana and Independiente was suitable for small trucks and is still accessible today in an all-terrain vehicle. There is clear evidence of the removal of spoil from the Guzmana tips.

6.8. An urban myth.

And finally, an urban myth. There was a belief that the Santa Barbara tunnel had been used by the Americans for the interment of soil contaminated with plutonium following the “nuclear incident” in Palomares. The basis for this erroneous story was a report in the Daily Mail newspaper about the disposal of the contaminated material. It reported that loaded trucks were to be seen entering a tunnel in the mountains and returning empty. Great secrecy and high security surrounded the Americans’ movements in Palomares and the reporter was at considerable distance from the activities. What he actually saw was trucks entering a deep cutting leading to the burial site and the mountain was simply one of the hills to the west of Palomares. It was a bit of lazy reporting to say the least, but for the locals, it was about the only piece of uncensored news that they read. They put two and two together and made five. Tunnel + Mountain = El Arteal. The fact that a truck couldn’t enter Santa Barbara due to restricted height didn’t seem to matter! It is a story that is still told, along with the one about dumping the waste down disused mine shafts. Both are without credibility.

Acknowledgements.

This work was never intended as a serious research document, but somehow it became a rather detailed study, not just of the Sierra Almagrera, but of lead mining and processing in general. Its haphazard development has now made it very difficult for me to acknowledge all of my sources. So many pictures and so much information was grabbed from internet searches, often after going down several pathways, that I have no idea where some of them came from. If I have used some of yours, dear reader, and have not acknowledged them, please accept my apologies.

My primary source was the book, Sierra Almagrera y Herrerías: Un Siglo de Historia Minera. [Cuevas del Almanzora, 1828-1936] by Enrique Fernádez Bolea. While fascinating, detailed and eminently scholarly it is not for the faint hearted. Google Translate renders its flowery prose almost unintelligible, a problem if, like me, you are not Spanish speaking. It is, however, the most well thumbed book that I have ever owned.

The other publication, this time a digital one, that became my secondary source was Hastial 2012, in particular, the article by Antonio Gonzáles Jódar and José Manuel Sanchis, called Desagües y Socavones de Sierra Almagrera, Cuevas del Almanzora, Almería. Reading it for the first time was like walking into Aladdin's cave!

In 2017, I was fortunate enough to meet Señors Bolea and Jódar by chance in the Barranco del Jaroso. Haltingly, I explained that I was writing some notes for English visitors to the area, and would they mind if I used information and pictures from their works. Both, unhesitatingly, gave me permission, for which I can’t thank them enough. Subsequently, Antonio Jódar has been kind enough to reply to my e-mail queries, and then, on reading the original copy of Then, There Were Mines, gently advise me of my errors.
It has also been my privilege to walk in the Sierra with him, and to benefit from his considerable knowledge of it.

Another notable authority on the history of mining in Andalucía is the scholar, Andrés Sanchez Picón. Together with Isabel Garcia Jiménez, he wrote the paper, Minas de Almagrera S.A. 1944-1958. El intento de una empresa de INI de revitalizar un distito minero tradicionel. This, together with, Sierra Almagrera. 100 años de lucha contra el agua, by Andres Navarro, took me, and the story of El Arteal, up to relatively modern times.

Just when I had started this almost complete re-write of the original text, there appeared on the internet a copy of Gustave Reinhold’s paper. entitled Pumping Station at Sierra Almagrera. which he had presented to the Institution of Civil Engineers in 1898. This was a great help to me in piecing together the early development of the El Arteal complex.

I found my way around the Sierra by using Google Earth and José Manuel Sanchis’s photographs of the various mines. These wonderful pictures can be found at mtiblog.com (localidades Andalucía). I have used some of them in this book when they illustrate a point better than one of my own photos. Quite often mti gives the co-ordinates for a mine’s location, so the track up to it can be found using Google Earth. Don’t worry if you miss the track on your first attempt, I frequently failed on even the third try.

A.G. Jódar’s blog Bayo los Espartales and Francisco Mulero Navarro’s El Portal de Sierra Almagrera gave some good background information and have wonderful images, taken by remote camera, of the depths of some of the shafts. Bajo los Espartales also has good then and now photographs.

While J.M. Sanchis is the present day chronicler of the remains of the mining industry in the Sierra Almagrera, tribute has to be paid to José Rodrigo Navarro as the 19th century chronicler. Between 1874 and 1883 he photographed so many of the mining installations in the area. His wonderful pictures give us so much insight into what it was like all those years ago. They say that a picture is worth a thousand words, but the detail and clarity of Rodrigo’s make them worth many thousands of words.

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