ROMAN GOLD-MINING IN NORTH-WEST SPAIN

By P. R. LEWIS and G. D. B. JONES

(Plates XVI–XXIII)

The Augustan conquest of the Asturias was resisted with all the tenacity native to that region, but under the combined pressure of no less than three legions, this wild and mountainous area of North-Western Spain finally capitulated in *c.* 25 B.C.[1] On the Roman side the prospect of mineral exploitation was a major motive that demanded at times the presence of both Augustus and Agrippa. The literary references to the Spanish mining-projects that followed the conquest do not specify particular sites, but indicate instead general areas where mining was initiated.[2] Fortunately, however, the gold-rushes of the last century in California and elsewhere reawakened interest in other areas of the world, and particularly this region of Spain, partly as a result of the legendary stories of Roman successes. The prospectors found many traces of those efforts, although in the main unsuccessful themselves. Part at least of what they saw was recorded in the current mining papers and journals of that period, and we are indebted to the work of O. Davies for abstracting and summarizing much of this information, which would otherwise be difficult to assimilate, the sources now being unobtainable or very inaccessible. We may be sure that the twenty or so mines that he noted are an underestimate, and that many more await discovery. Although Davies' list was made over thirty years ago, none of the sites have since been surveyed in any detail and no photographic record exists.

The region of interest lies to the west of León, the base of Legion VII Gemina,[3] in the present provinces of Galicia, Orense and León. Most of the sites lie either in or close to river beds, particularly those of the Sil, the Duerna, the Miño, the Narcea, the Navia and their respective tributaries. The Sil and the Miño unite to flow south-west into the Atlantic, the Narcea and the Navia north into the Bay of Biscay. The watershed between the two systems, the Somiedo Mountains, forms a natural boundary. The mountains, with the vein gold they contain, are also the original source for the alluvial and placer-gold deposits found in the rivers that flow from them.[4] We may be sure that the Romans discovered this at an early stage, for there are records of at least ten deep mines in the Somiedo Mountains.[5] Moreover, natural weathering of the gold veins has produced a series of secondary occurrences, either as high-level alluvial deposits or low-level placer deposits in the river valleys. The former are, of course, geologically much older than the placers, often having gone through several cycles of uplift and subsequent erosion. They are thus usually easy to find, being in most cases surface deposits and easy to treat in comparison with vein gold, since they contain a larger proportion of free gold. From the analogous history of the great gold-rushes in California and Australia, we might expect that it was the discovery of gold in these ores that first stimulated Roman interest in the region. Once they had been exhausted, prospectors would have turned to the primary sources higher up in the mountains.

The distribution-pattern that emerges from the known sites remains that originally charted by Davies, and is shown in fig. 23. The main division between the mining sites is twofold: there are those that lie in the valley of the Sil and its upper tributaries, a group to which both Montefurado and Las Medulas belong (Nos. 1 and 2 in fig. 23); and, secondly,

[1] For the classical topography of the area, see E. A. Schulten, *Iberische Landeskunde: Geographie des Antiken Spanien* (1955), also published in a Spanish translation (1959). For the Augustan campaigns, see D. Magie, 'Augustus' War in Spain', *Class. Phil.* XV (1920), 323 ff., further discussed with some topographical modifications by R. Syme, 'The Spanish War of Augustus', *Am. J. Phil.* LV (1934), 293 ff., and E. A. Schulten, *Los Cantabros y Astures y su guerra con Roma* (Madrid, 1946). See also now A. Brancati, *Augusto e la Guerra di Spagna*, Pubblicazione dell'Università di Urbino xvii, 1963.

[2] Pliny, *NH* XXXIII, 67–78, fully translated and discussed in the appendix. A list of general references by classical authors to minerals in Spain is given by Schulten (*Landeskunde* 223; Spanish ed., vol. ii) and O. Davies, *Roman Mines in Europe* (1935), 94 f. Cf. also Sil. Italicus I, 228 ff.

[3] I. A. Richmond, 'Five Town Walls in Hispania Citerior', *JRS* XXI (1931), 91 ff.

[4] For a brief discussion of the nature of gold deposits, v. P. R. Lewis and G. D. B. Jones, 'Dolaucothi Gold Mines I: the Surface Evidence', *Ant. J* XLIX (1970), 244 ff. A more extended discussion is given by M. Maclaren, *Gold, its geological occurrence and geographical distribution* (1908), *passim.*

[5] Davies, op. cit., 103.

those that straddle the watershed of the Somiedo Mountains. To the sites noted by Davies have been added several where the modern Spanish name (such as *Rio del Oro*) clearly implies the working of placer-deposits. These sites should not be accepted uncritically as representing simply the sum total of gold mines. Very few mines yield a single mineral or ore, most produce a spectrum of several minerals. The detailed attribution for each particular mine can only be worked out by individual examination on the ground.

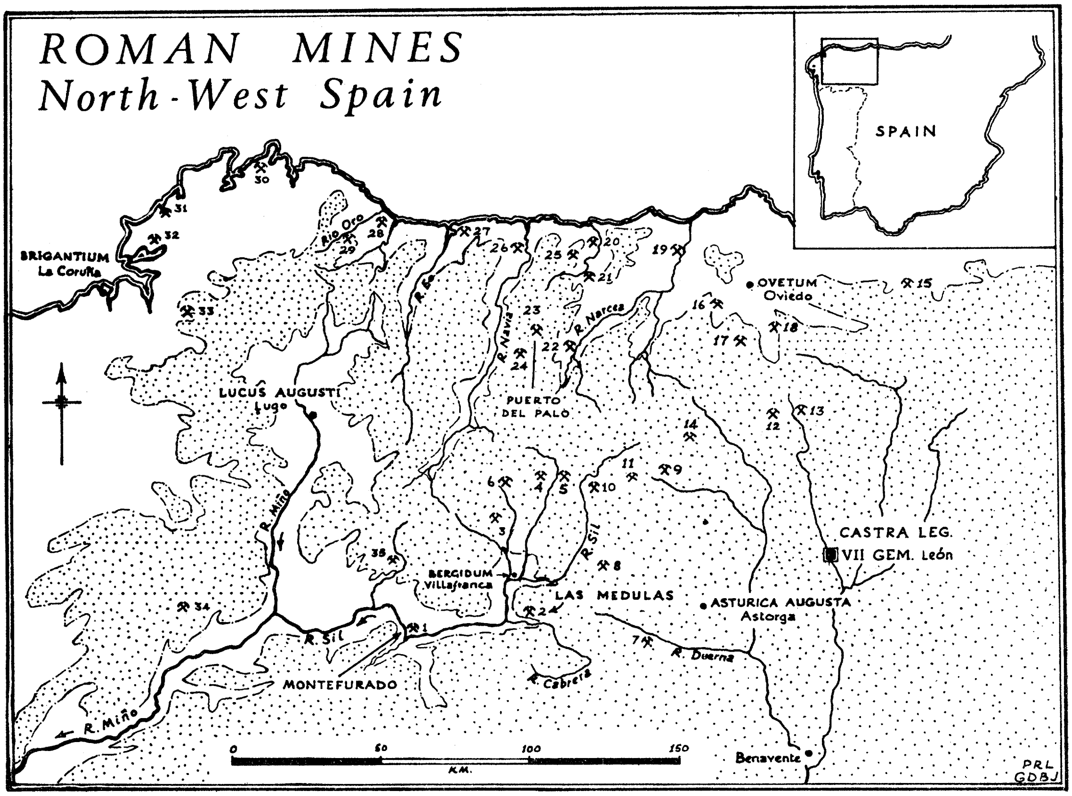

FIG. 23. DISTRIBUTION MAP OF ROMAN MINING SITES IN NORTH-WEST SPAIN. THE CONTOUR IS DRAWN AT THE 800 M LEVEL. NOT ALL THE SITES ARE GOLD MINES. TIN, IRON AND COPPER WORKINGS ARE KNOWN AS INDICATED. Key: (1) Montefurado, (2) Las Medulas, (3) Paradeseca, (4) Menival, (5) Anclares (mines along the valley of the R. Anclares), (6) Burbia (mines along valley of R. Burbia), (7) Duerna Valley (17 mines, including Los Castellones), (8) Rio Boeza, (9) Murias, (10) Paramo del Sil, (11) Salientes, (12) Pontedo (copper), (13) Villamanin (copper), (14) Peñalva, (15) Milagro (copper ?), (16) Ablaneda, (17) Sierra Aramos, (18) Ortguera, (19) Pravia (lead), (20) Trevias, (21) Fornones, (22) Vegalagar, (23) Puerto del Palo (= Cueva de Juan Rata ?), (24) Valle del Oro, (25) Naraval, (26) Carcobas de Miudes (iron), (27) Slabe (Castropol) (tin), (28) Via de Foz (copper), (29) Rio de Oro, *cf.* no. 24, (30) Punta de la Estaca de Vares (iron ?), (31) Valdovinos, (32) Ferrol, (33) Monfero, (34) Carballino, (35) Lor Valley.

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INTRODUCTION

Our intention is to provide a survey of three mines, Montefurado, Las Medulas and Puerto del Palo, that are geological type-sites. From a reconnaissance-visit made in 1967 by one of us (P. R. L.), supplemented with more recent work by both authors and Mr. D. G. Bird,[6] and from comparable evidence now available from Britain, we now know that the sites exemplify the three main types of mine, i.e. placer, alluvial and hard-rock, a point that did not emerge clearly in previous scattered references to the sites. Las Medulas may certainly be regarded as one of the best preserved alluvial mines of the Roman period. Montefurado proved to be more complex, showing elements of placer and vein mines that

[6] Mr. Bird is currently undertaking a comprehensive survey of the mining sites of the region for a postgraduate thesis.

have been heavily re-worked at a later period. A similar situation is known at Dolaucothi, the only Roman gold-mine so far known in Britain; originally thought to be solely a deep mine,[7] it too has been shown to preserve extensive traces of placer-mining.[8] Las Medulas remains a good example of a high-level alluvial mine that never developed the secondary characteristics typical of Montefurado and Dolaucothi. By contrast, Puerto del Palo presents an excellent example of an opencast vein mine operating at an altitude of over 1,000 m; like Las Medulas it was never re-worked after the end of Roman activity. Whatever their complexities, these must all represent major sites in comparison with the others so far known in North-Western Spain, if one may judge from the size and elaboration of the hydraulic systems at Las Medulas and Puerto del Palo, and from the placer-mining tradition inferable at Montefurado.

The exploratory survey of the three sites involved fieldwork techniques originally developed at Dolaucothi in South Wales, but which could be applied in Spain, *mutatis mutandis*. Corroborative excavation has not been attempted at the Spanish sites, although at Dolaucothi the evidence from excavation confirmed and supplemented the information already available from fieldwork. In Spain, however, fieldwork had to take first place, for a number of reasons. The literature on the Spanish mines is diffuse and repetitive, being partly based on local folklore rather than the actual remains. Moreover, the visible features in Spain tend to be related in a much more obvious way to local geology and geomorphology than those of the British mine.

The discussion of the sites is divided into two parts: description of the primary remains and of the topographical setting followed by detailed interpretation based on the internal logic of each site, as well as on the analogous evidence from elsewhere. Finally, the theory and practical techniques involved are discussed, and the possibilities for future work.

MONTEFURADO

Description. About a kilometre above the point at which the Rivers Sil and Bibey join stands the small village of Montefurado. The village itself lies within walking distance of the group of features and remains from which it takes its name, the gold-mine of Montefurado. The immediate topography of the site is shown in pl. XVI and fig. 24.

The mine lies on and around a double-swing meander somewhat more sharp than those usually encountered at irregular intervals in the river beds of this region.[9] Whether or not local geological factors have been solely responsible for the formation of this feature remains unclear owing to lack of detailed information.[10] Broadly, the bed-rock (as can be seen clearly in pl. XVII, a, b, c) consists of highly distorted strata of Cambrian slates and mudstones, which at several points have been subjected to strong mineralization. The village lies just opposite the undercut slope that dominates the first inswing of the meander, as seen in the centre of pl. XVI. As is apparent from pl. XVII, a, b, the river runs in a fairly deep gorge within its own bed from a point somewhere below the two dams (A and B on pl. XVI) which are situated just at the start of the slip-off slope of the spur. The level of the water is abnormally low in these plates, partly because of climatic conditions (they were taken in late summer), but primarily because of the current programme of hydro-electric schemes in the region.

The second spur of the feature, La Vega, consists of a steep promontory which at its highest point rises some 65 m above the river bed. The neck of the spur contains the primary auriferous intrusions (pl. XVII, a), at which point the rock face falls almost vertically 60 m to the river below. The south-western side, by contrast, has been severely gashed

[7] A recent general survey by W. H. Manning, *Antiquity* XLII (1968), 301, over-emphasized this aspect, following G. C. Boon and C. Williams, *JRS* LVI (1966), 122, n. 6.

[8] Lewis and Jones, op. cit., 246. A more detailed discussion is given by Jones and Lewis, *Carmarthen Antiquary* VI (1970).

[9] Geomorphological terms, if not immediately obvious, may be found in several textbooks currently available, for example A. K. Lobeck, *Geomorphology: an Introduction to the Study of Landscapes* (1939). A broad survey of the physical geography of North-West Spain is available in M. Terán, *Geografiá de España y Portugal* (Barcelona, 1952) I, ch. 12.

[10] A description of the geology in the province of León is given by J. A. Jones, *Trans. Fed. Inst. Mining Eng.* XX (1900–1), 420 ff. It is not known if any more detailed geological surveys of the region have been made subsequently.

from a point about 50 m above the line of the river bed, and consists of a sheer, if not overhanging, rock face. This western outcrop is largely pyritic, while virgin gold ore appears to outcrop further east (pl. XVII, c). This forms the most striking evidence of bed-rock mineralization. The river at present flows through a gap at the base of the escarpment, which is shown in detail looking downstream in pl. XVII, b. The rock arch is clearly of some antiquity, hence its survival in the name Montefurado (*mons foratus*, the pierced mountain) and in its second name, Boca do Monte, the hole in the mountain. The cut-off has thus isolated a considerable portion of the meander, of which the larger part consists of dried-up river bed (shown at right in pl. XVI), although there is a small oxbow lake at the

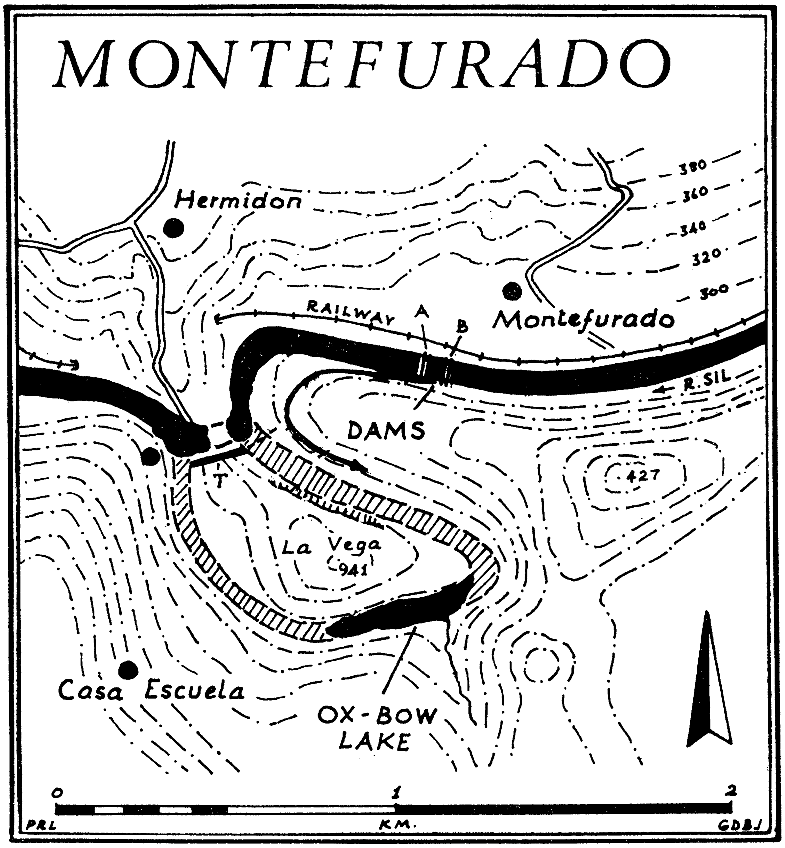

FIG. 24. GENERAL PLAN OF THE MONTEFURADO SITE. T = TUNNEL

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farthest end of the loop (the tip of the lake can be seen in the extreme right of pl. XVI, a). The old river bed lies some 8–9 m above the present river gorge.

The most obvious archaeological feature of the site is the deep canal (*c.* 3 m deep by 3 m wide) that runs from the pair of dams, closely following the contours of the slip-off slope, and eventually disappears into the old river bed (fig. 24). Of the two dams the upper one, dam B, is of recent origin.[11] Its massive slate-and-concrete construction contrasts markedly with the remains of another dam (A) slightly downstream. The latter is relatively slight in construction and consists simply of a coarse concrete matrix.

Apart from one section in the bend of the inswing, where river scour has revealed its full section, most of the canal is now choked with detritus. Approximately 40 m beyond the point where a breach has occurred in the outer wall of the canal, the channel disappears

[11] Probably built at the end of the last century by a German company based on Ponteferrada: M. Breidenbach, *Zeit. prakt. Geol.* 1893, 16. A protective overlay of river debris (now removed) may best explain the survival of this feature in its foundation courses.

altogether into the old river bed. But fortunately one onward continuation (on a line rather different from the former alignment along the river bend) can be traced as a line of stones bonded with concrete, that projects a few centimetres above the present silt level. This leads to a tunnel that has been driven straight through the rock-face of La Vega, about 20 m south of the river-gap described above; the size of the arched tunnel (*c.* 2 m wide by 3 m high) compares with the dimensions of the canal. It is 180 m long and contains shot-holes, a feature that was not found anywhere along the canal. If the tunnel was designed to explore a southward branch of the principal area of mineralization, then no veins of significance were found, and very little scour is evident at the western exit. However, to the south the main branch of the canal must have continued some way along the edge of the dried-up meander. At one point here, the derelict washing tables of nineteenth-century exploitation can be seen (pl. XVI, b). No clear evidence for an earlier period was traced in this area, but placer-pitting along the banks of the meander suggests that similar working of placer-deposits had occurred in an earlier phase.

Analysis. The features described present three problems. First and foremost, how can the ancient phases of mining be recognized with any confidence? Second, how are the extant archaeological remains related to the visible geomorphological features? Last, does the interrelation of the two kinds of evidence gives us a coherent picture of the way in which exploitation proceeded?

The mine does not at present exhibit any direct evidence of working in Roman times, such as an inscription or graffito on a rock-face. The indirect evidence, however, is strong. Montefurado was known in local tradition prior to any modern attempt to re-exploit it. Moreover, among the mining areas of the Sil valley, Montefurado appears to have been one of the richest and could therefore hardly have been ignored. The explanation given by Beuther[12] and repeated by Davies[13] for the tunnel—which has tended, like the underground features at Dolaucothi, to monopolize attention—seems obscure and unsatisfactory. The difficulty lies in a confusion of the archaeological and geomorphological features, which must be analysed separately before any reconstruction. Davies gives two possible explanations for the tunnel: either it was used to divert the river in order to attack deposits in its bed at unspecified points, or it was used to bring a supply of water to a mine lower down the valley. The latter suggestion can be eliminated immediately, for there is no trace of a continuation of the canal at any point beyond the tunnel exit, and there are no known workings between this point and the confluence of the Sil and Bibey, a full kilometre away.

The occurrence of primary mineralization in the neck of La Vega and the gash which occurs in an upstream direction strongly point to opencast working of the rock-face. While at first glance one might suspect a natural origin, the depth of the gap, its direction and the relatively rapid rate of erosion to be expected from a young river all argue for an artificial origin for the present course. Once the rock-gap through which the Sil runs is understood to be a man-made cutting, then it is possible to explain how the site has come to have its present shape and appearance. As opencast working from the rear of La Vega progressed, the point when collapse of the eastern wall (preceded by extensive seepage through the mudstone) occurred would eventually be reached. The situation would have been even more critical if the richer veins were near or even below river level, as implied by the depth of the river gorge. For these, a coffer dam of some kind would have been essential; it could not, however, have survived the winter torrents for which the Sil was notorious before it was regulated by the present hydro-electric schemes.

While the development of an opencast on the downstream side of La Vega can thus be postulated, there are problems concerning the remaining features. Neither of the two dams is demonstrably ancient, but if the Roman miners worked the opencast through to the upstream side of La Vega and attacked the actual bed of the Sil (as seems to have occurred from the 8–9 m drop in level, p. 172) then a dam must be postulated upstream at roughly the same point as the surviving examples. While the straight tunnel through La Vega exhibits shot-holes, the canal itself does not. Likewise, as already suggested (pp. 172–3),

[12] W. Beuther, *Zeit. Berg-Hütten-Salinenwesen preuss. Staat.* XXXIX (1891), 55.

[13] Davies, op. cit., 102.

the canal does not lead directly to the tunnel and the lateral feeder channel may be secondary. Possibly, therefore, the various features are not contemporary, but the decisive evidence now lies buried beneath the tons of silt choking the old river bed. By itself the canal is a useful reminder of the major role of placer-mining in the Montefurado complex.[14] Thanks to the nineteenth-century workings, it is impossible to point to placer-workings of specifically Roman date, much of the evidence for which would, in any case, disappear with each winter's flooding. Indeed, upstream every major meander of the Sil exhibits the tell-tale rock piles of placer-workings. Although many of the details escape us, at Montefurado we are dealing with a more sophisticated stage in which Roman miners worked not merely the placers but also traced and attacked part of the parent ore body from which they derived.

LAS MEDULAS

Description. About 40 km from Montefurado up the Sil valley lies one of the largest and most distinctive outcrops of the quaternary alluvial deposits of the region. The exact extent of the formation has not been charted,[15] but the characteristic bright-red deposits may be seen either as a terrace along the Sil basin and other adjacent valleys, or as isolated masses in the case of Las Medulas. The formation here is very extensive, lying at its highest point *c.* 1,000 m above sea level, and stretching for some kilometres around the village of Las Medulas. The salient topography is shown in pl. XIX, a, looking north-west, the village lying at the extreme left of the panorama. The fantastic ' badland ' weathering, and particularly the knife-edges and pinnacles that have formed in front of the retreating scarp to the right, illustrate well the erosive nature of the deposit.[16] The older slates upon which the deposits rests can be seen in the lower plate (XIX, b), taken at a point 6 km to the south-east on a tributary of the Sil, the Cabrera. The site lies just over the ridge to the extreme left beyond the village of Pombriego in the foreground.

Closer inspection of the escarpment, 30–40 m high (pl. XIX, b), shows that it consists of numerous irregular bands of fine sand and clay dispersed in coarse conglomerate. One result of the weathering process is evident in the caverns existing in its face (pls. XVIII, b ; XIX, b). It may be suggested that the formation of caverns, and their enlargement by internal erosion, followed by roof-collapse, eventually gives rise to the much-dissected ' badland ' scenery.[17] In such a deposit, placer gold may be expected to occur only in certain bedding-planes. Much of the deposit, whatever the exact proportion, may have had no gold at all, and merely constituted waste overburden.[18]

The extant archaeological features were noted several times at the turn of the century by mining engineers, and have been summarized by Davies.[19] Of these accounts those of Del Mar [20] and Longridge [21] (both extensively quoted by O'Reilly [22]) and lastly J. T. Jones [23] are probably the most perceptive. As for Montefurado, there is little earlier information in Spanish sources.[24] The date of the site is attested by the Roman artefacts discovered by Longridge and the find of a Neronian *aureus* in the course of a sluice.[25]

The most important surviving remains are the three large aqueducts, 2–3 m broad, entering the site from the south-east at about the 950 m level (fig. 25). The lower two systems skirt the southern ridge of the deposit (between spot heights 1,012 m and 973 m), ending in the series of tanks and reservoirs (shown in fig. 25). Judging from the numerous large and small opencasts in the area, it is clear that a considerable portion of the ridge has been removed by hydraulic action (pl. XXI, a, b). The interpretation is reinforced by the

[14] M. Maclaren, op. cit., and R. W. Paul, *California Gold: the Beginning of Mining in the Far West* (University of Nebraska, 1947), 153 ff., explain the practice of hydraulicing placers.

[15] J. A. Jones, l.c., fig. 1.

[16] R. W. Fairbridge *ap. The Encyclopedia of Geomorphology* (Reinholdt, 1968), s.v. Badlands.

[17] Lobeck, op. cit., 388 ff., gives an extensive discussion of the subject of loess weathering by a similar mechanism.

[18] A sample taken from the roof collapse of the cavern shown in pl. XVIII, b showed zero trace of gold. (The analysis was performed using X-ray techniques by the good offices of Dr. J. M. Anketell, Dept. of Geology, Manchester University.)

[19] op. cit., 102.

[20] A. Del Mar, *Australian Mining Standard*, 25th April, 1906, 399, concluded in issue of 2nd May, 1906, 429.

[21] C. C. Longridge, *Mining Journal*, 29th January, 1898, 139.

[22] S. O'Reilly, *Proc. Roy. Irish Acad.* Ser. III, vol. VI (1901–2), 63 ff.

[23] loc. cit., 427.

[24] For example, *Revista Minera* XLIV (1893), 36.

[25] Del Mar, loc. cit.

existence of an extensive group of tanks sandwiched between the two largest opencasts directly below spot height 973 m. All the tanks at this point compare well in overall dimensions with the more easterly ones, not exceeding 100 × 20 m in size and roughly 1·5 m deep. In several cases the stone sluice-gates are very well preserved, and in at least one example (the highest tank below S.H. 973 m) the inflow channel can easily be traced. This set of tanks is now completely isolated from the primary inflow aqueducts, as illustrated in pl. XXI, a. The photograph was taken from the ridge overlooking the middle opencast to the east, and the two aqueducts can be traced along the hillside shown in the right-hand side of the plate. The most westerly open-cast is seen in pl. XXI, b, with the corner of the scarp in the extreme left-hand corner. The series of cone-shaped rock piles along the edge of the working is very similar to some features observed at the mine of Los Castellones in the Duerna valley.[26] Finally, the scarp face of the middle opencast contains a series of short tunnels (many now in an advanced state of collapse), a northward-facing example of which can be seen from the modern village below. The interior of the tunnel presents a two-phase sequence, one tunnel having been driven directly over an earlier adit. The appearance of the lower tunnel presumably gave rise to erroneous reports of aqueduct-channels within the deposit.[27]

The aqueduct that follows the northern side of the ridge is shown in pl. XX, a, at a particularly interesting point where several phases are involved. The earliest period is represented by the aqueduct-ledge at the extreme right of the picture, which is now cut by a modern track running almost parallel to its course. The ledge ran to a long ' hush-gulley ' that dropped down the north face of the ridge (fig. 25). The same technique was used at a later stage as shown by the two deeply-incised gullies running from the aqueduct course in the right of pl. XX, a. The final phase is represented by the superimposed course of a lower aqueduct in the deeper of the two ravines. It is clear that this system fed the rest of the site to the north with an adequate supply of water. The aqueduct can actually be traced as a line of stones in the modern track leading to the village of Orellan. By contrast with the collecting systems on the south ridge, the corresponding reservoirs at this point (A) and further north (B) are much larger, measuring 200 m × 40 m × 3 m and 160 m × 40 m × 5 m respectively (fig. 25). The latter tank was fed from tank A (shown in the right foreground of pl. XX, a) by an aqueduct circling spot height 951 to the rear of the main escarpment. Long, deep gulleys run down from each tank, the more impressive series being from tank B where some of the channels follow the contours to the edge of the opencast (fig. 25). The tunnels of the south ridge are paralleled by similar features in the main escarpment, particularly by a tunnel under tank A leading directly to the face beneath tank A, and others radiating inwards from caverns elsewhere in the face of the main opencast. In cross-section the arched tunnels normally measure roughly 2·5 m high by 2 m broad. Further traces of mining are not evident.

Longridge and Del Mar noted that the site was served by a series of aqueducts of varying length (claimed to be between 25 and 40 kilometres) but unfortunately left no details. The aqueducts number in fact no less than seven, the largest group associated with any Roman mine. The complete series are intermittently visible as lines on the upper slopes of the Cabrera valley in pl. XIX, b, cf. fig. 25 (upper). There is a height difference of *c.* 400 m between the upper and lower systems, that must be related to the development stages of the mine itself. It seems clear that the upper aqueduct never reached the site at all, being rather designed to explore or work deposits on the slopes of Cruz de la Peña east of Las Medulas. The next three systems, however, served the site in the form in which it survives, and have already been described. The three lower aqueducts were probably intended to explore and work the lower slopes of the south ridge, but mining activity at the higher level has obliterated their final destination.

Although the aqueducts have not been surveyed in detail, local tradition suggests that the sources lay in the area of Castrillo de Cabrera in the valley of the Cabrera proper, over twenty kilometres distant from the mine. There is no reason to doubt this report, which,

[26] Recently surveyed by Mr. R. F. Jones of Manchester University, in collaboration with Mr. D. G. Bird.

[27] Davies, op. cit., 102.

allowing for contours, would give the aqueducts a length of over fifty kilometres. Pl. XIX, b, shows the aqueduct channels above and north-west of Pombriego. The most spectacular section observed lies six kilometres further east and below the summit of Guiana (1,848 m), where the Cabrera valley has been deeply indented by a tributary. Pl. XX, b, shows some of the aqueduct channels running across cliff, scree and mountainside. Nothing could better illustrate the spectacular problems of aqueduct construction described in Pliny, *NH* XXXIII, 75, and discussed in App. I (p. 183).

Analysis. The problem presented at Las Medulas is in one sense much simpler than that at Montefurado. There can be very little doubt that the extant archaeological features are

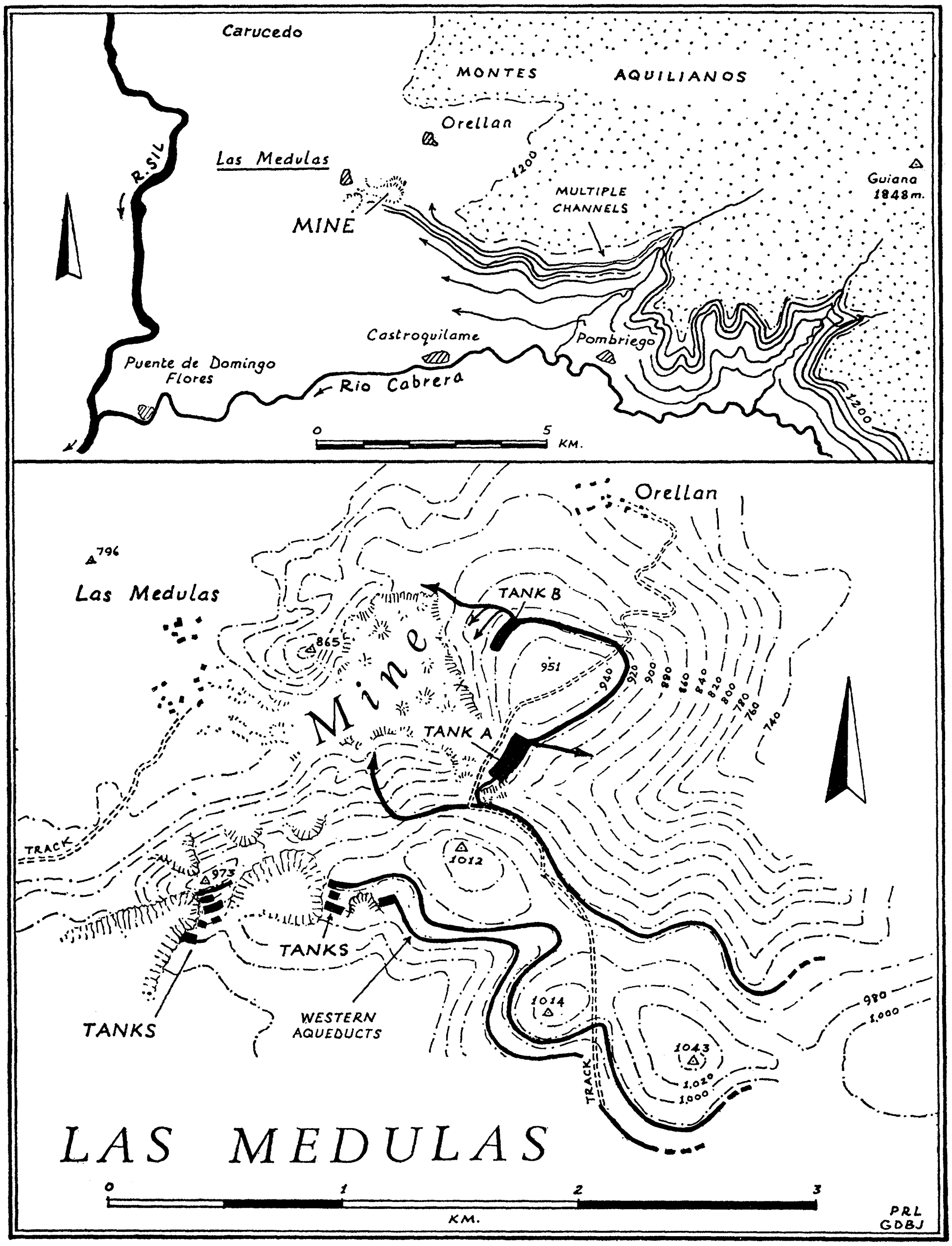

FIG. 25. LOCATION MAP AND GENERAL PLAN OF THE LAS MEDULAS MINE

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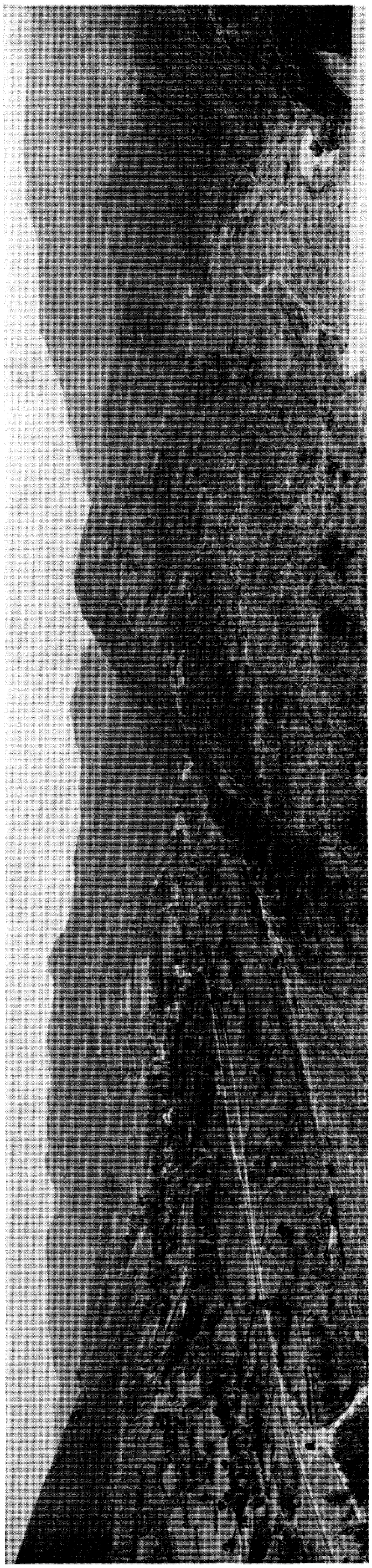

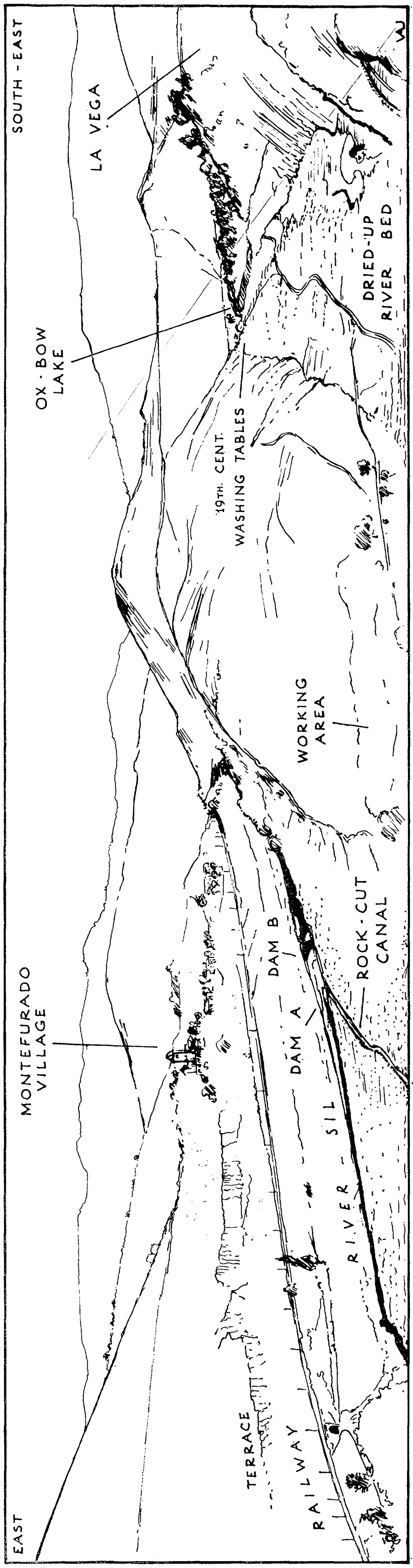

a, b, PANORAMA AND EXPLANATORY DIAGRAM OF THE SIL VALLEY AT MONTEFURADO LOOKING FROM EAST TO SOUTH-EAST (see p. 171 f., fig. 24)

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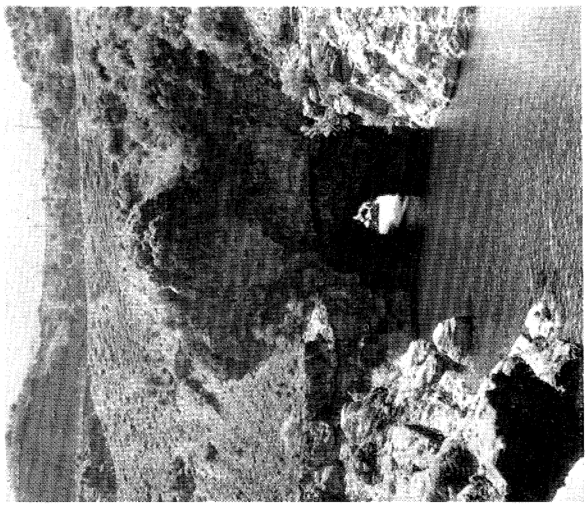
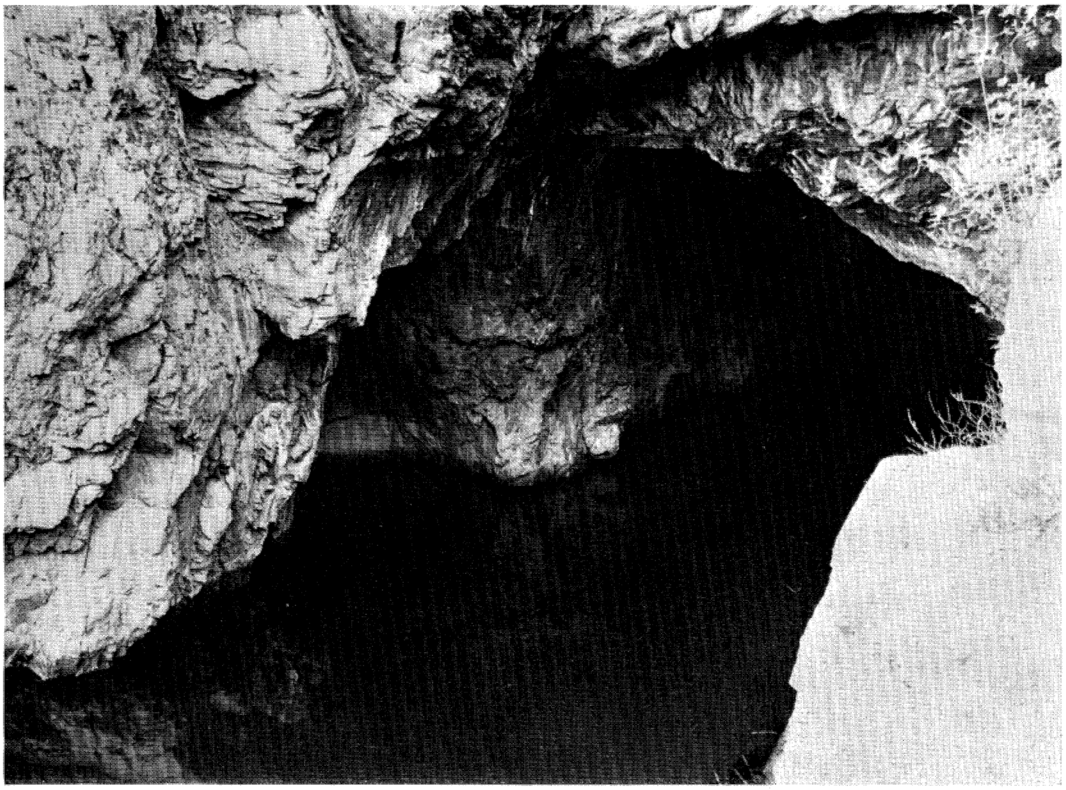
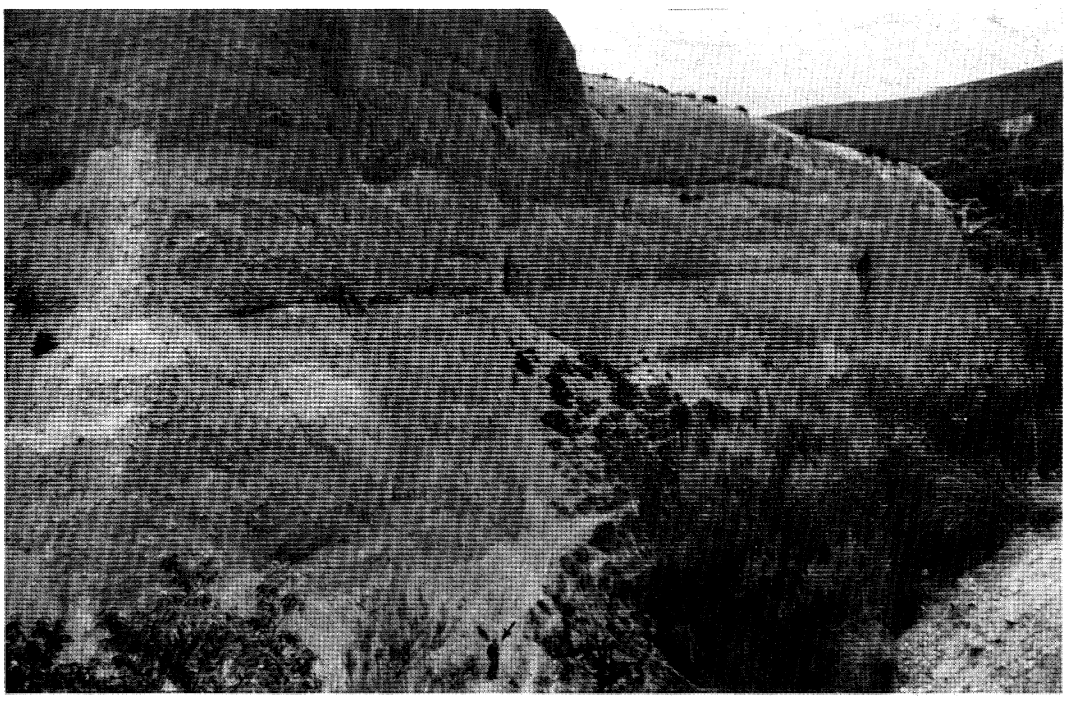
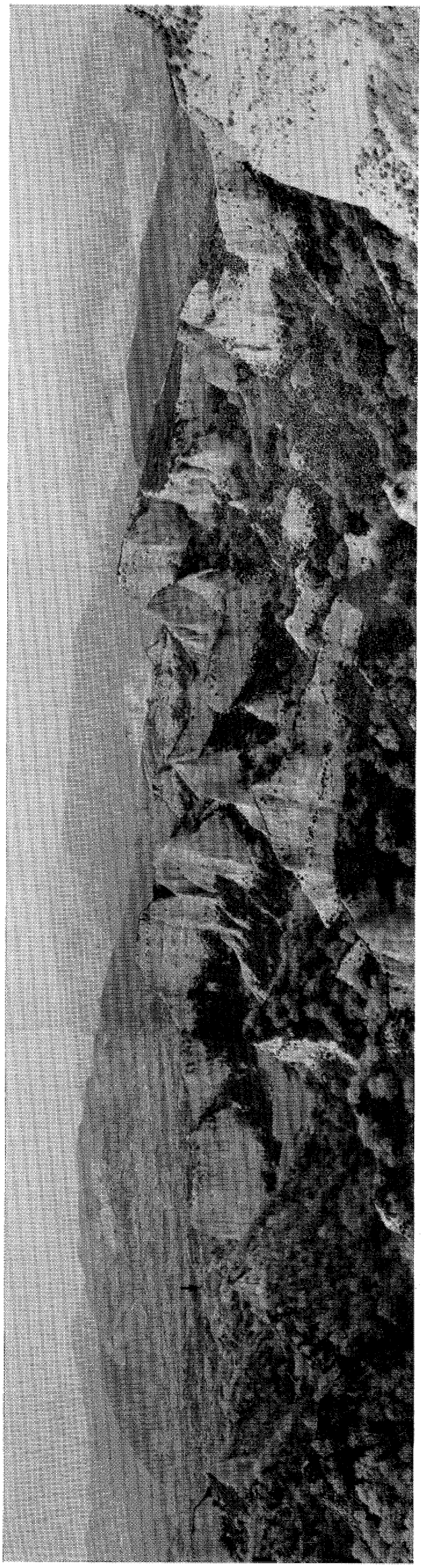


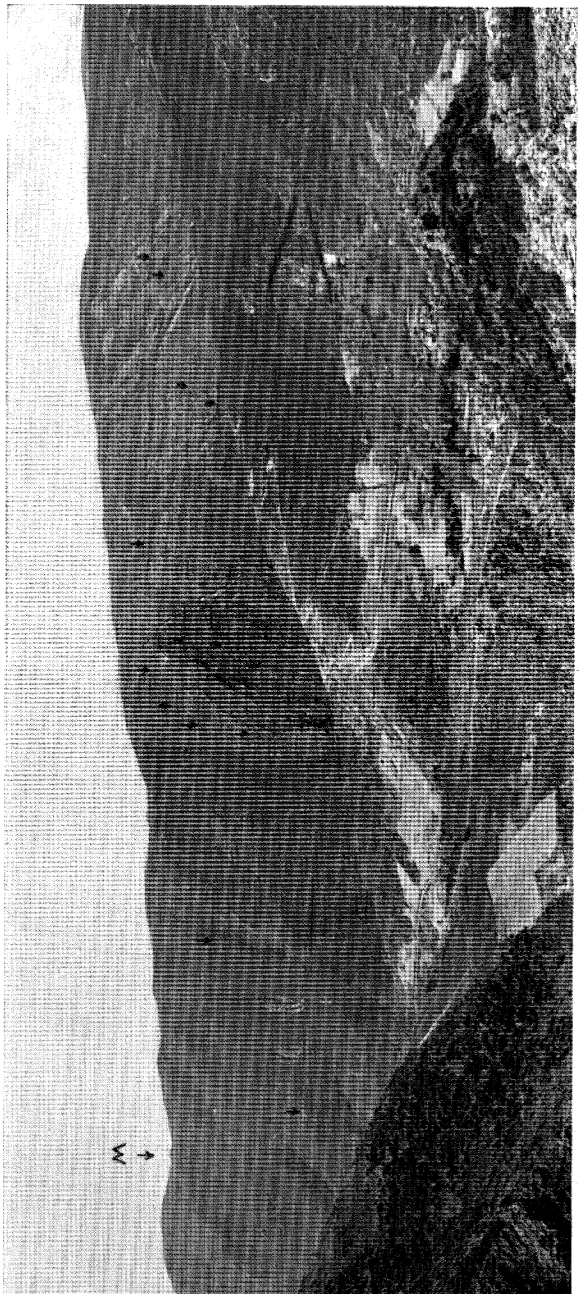
MONTEFURADO: (*a*) GENERAL VIEW OF THE SIL SHOWING THE RIVER TUNNEL AND OLD RIVER BED, TAKEN FROM NORTH-EAST. (*b*) THE RIVER TUNNEL FROM THE UPSTREAM (EAST) SIDE. (*c*) THE RIVER TUNNEL AND OPENCAST FROM THE DOWNSTREAM (WEST) SIDE SHOWING THE PRIMARY MINERALIZATION (CENTRE)



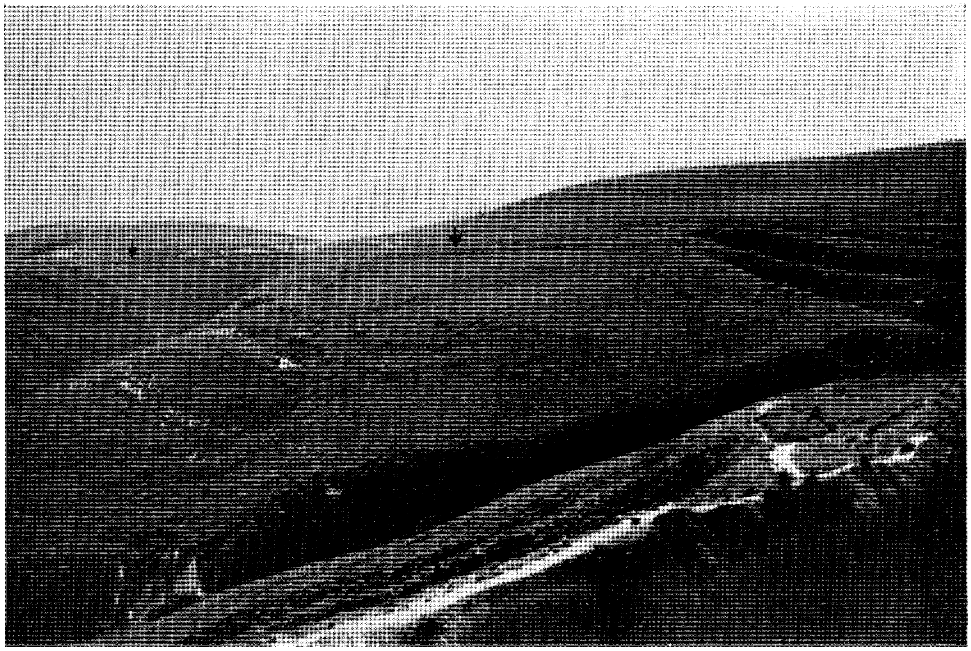


(*a*) MONTEFURADO: DETAIL OF THE RIVER TUNNEL SHOWING THE ROCK-CUT CORNER ON THE EASTERN SIDE.
(*b*) LAS MEDULAS: PART OF THE ESCARPMENT IN THE MAIN MINE SHOWING HORIZONTAL BANDING OF CLAY, SAND AND GRAVEL (see p. 174 ff.)





LAS MEDULAS (see p. 174 ff., fig. 25): (*a*) PANORAMA OF THE SITE, LOOKING WEST. (*b*) TRACES OF AQUEDUCT CHANNELS (ARROWED) ON THE MOUNTAINSIDE ABOVE POMBRIEGO. THE MINE LIES OVER THE MOUNTAIN RIDGE AT THE EXTREME RIGHT



LAS MEDULAS (see p. 174 ff., fig. 25): (*a*) THE MAIN AQUEDUCT LEADING IN FROM THE SOUTH-WEST. THE GULLIES LEADING FROM AQUEDUCT LEVEL REPRESENT DIRECT HYDRAULICING OF THE SOFT AURIFEROUS DEPOSIT. THE REMAINS OF TANK A CAN BE SEEN IN THE FOREGROUND

(*b*) THE LINES OF THREE ROCK-CUT AQUEDUCTS (ARROWED) SERVING LAS MEDULAS ON THE SLOPES BELOW THE PEAK OF GUIANA (see fig. 25). TELEPHOTO VIEW FROM SOUTH-WEST

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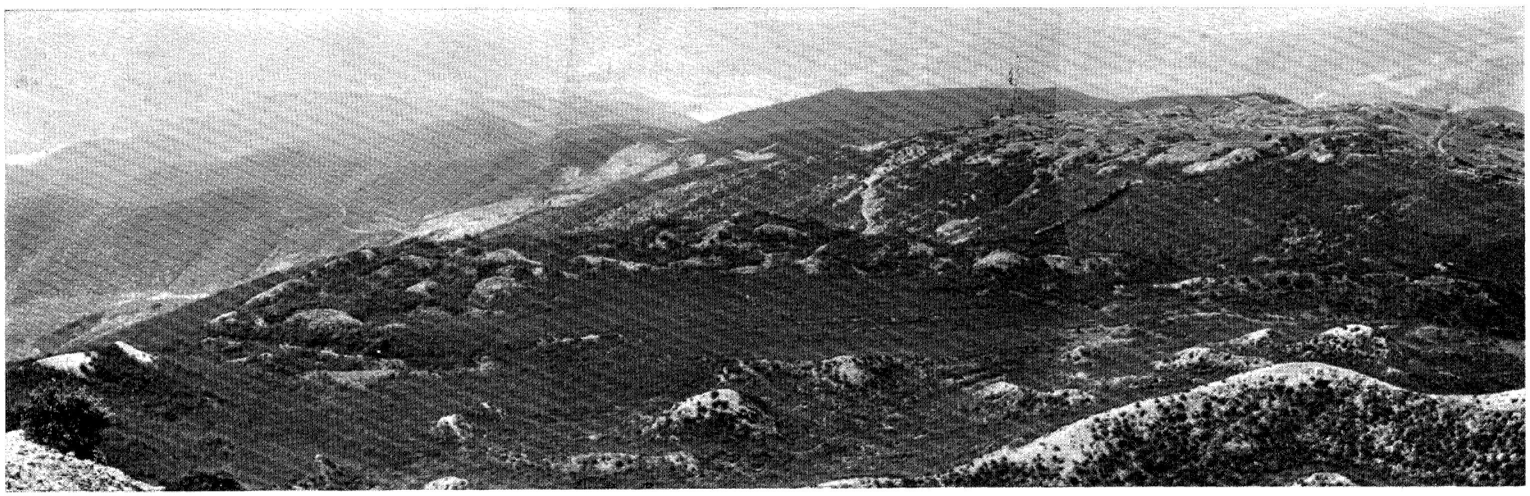
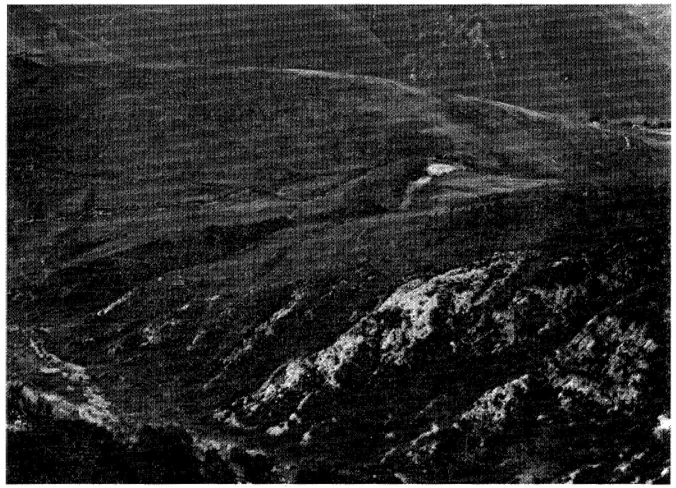
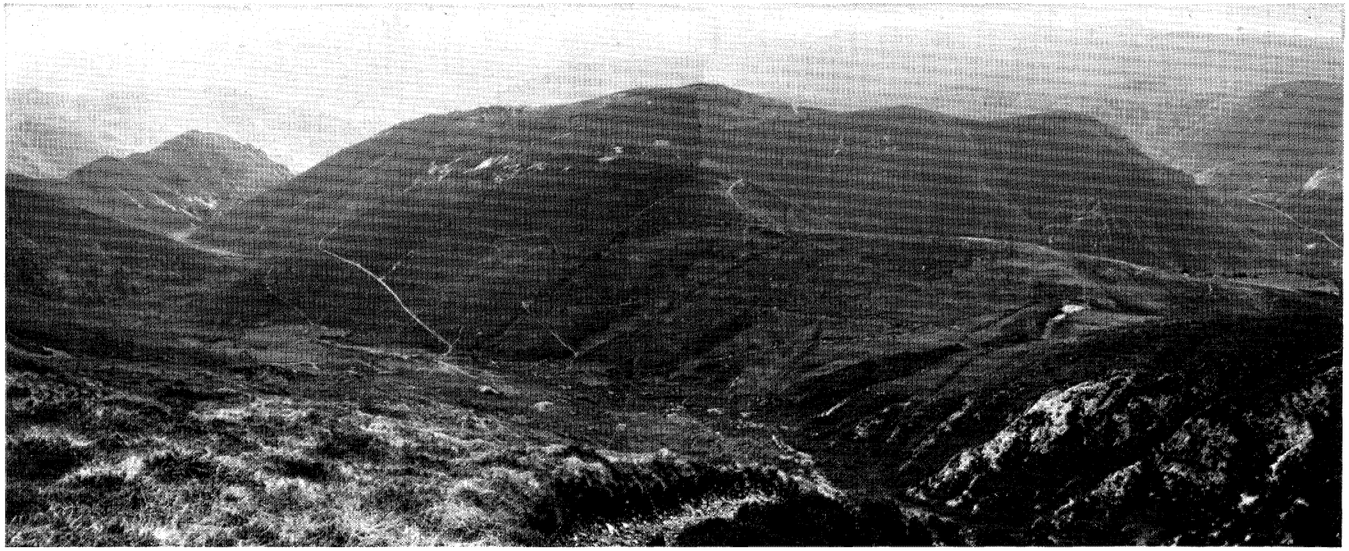
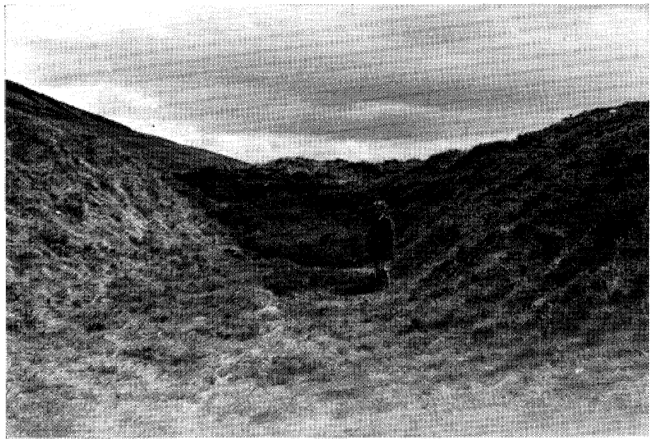


LAS MEDULAS: (*a*) GENERAL VIEW OF THE WESTERNMOST OPENCAST ON THE SOUTH RIDGE. THE AQUEDUCTS SERVING THE WORKING RUN ACROSS THE MOUNTAINSIDE ON THE UPPER RIGHT. (*b*) ROCK PILES FROM WASTE CLEARANCE AT THE FOOT OF THE SMALL OPENCAST BELOW SPOT HEIGHT 973 METRES, SOUTH RIDGE (see p. 174 ff., fig. 25)



PUERTO DEL PALO (see p. 178 ff., fig. 26): (*a*) GENERAL VIEW OF THE MAIN OPENCAST FROM THE SOUTH. A HUMAN SCALE IS SHOWN ON THE EXTREME LEFT. (*b*) VIEW SOUTH FROM MONTEFURADO (NR. LAGO) ALONG THE VALLEY OF THE RIO DEL ORO. THE MAIN AQUEDUCT SERVING PUERTO DEL PALO IS VISIBLE ON THE LEFT. (*c*) THE FOOT OF THE OPENCAST AT PUERTO DEL PALO WITH (ABOVE) THE TWIN RESERVOIR OF THE NORTHERN AQUEDUCT





PUERTO DEL PALO: (*a*) GENERAL VIEW OF WESTERN RIDGE. THE AQUEDUCT EXTENSION TO TANK C (see p. 178 ff., fig. 26) CAN BE SEEN AND BEYOND IT THE EXPLORATORY GULLY RUNNING DOWN THE SLOPE AND CROSSING AN EARLIER AQUEDUCT LINE. (*b*) THE INTERIOR OF TANK A. (*c*) THE OUTFALL FROM TANK A

Roman in date, and probably belong to the early imperial period on the evidence of the Neronian *aureus*. There is no evidence of later working to the scale implied by the aqueduct systems. The site is an archaeological fossil formed at the moment when the aqueducts ceased to flow, for the height of the Medulas site prevented later large-scale exploitation unless conducted by hydraulic means on a similar scale. For any assessment of the mine, the amount of natural weathering after the Roman abandonment therefore becomes of paramount importance.

The problem of reconstructing the site in its pre-Roman state remains daunting, primarily because of the difficulty in assessing how much material has been removed by hydraulic mining in the Roman period (*v.* App. II). It is apparent that the *c.* 34 million litres of water a day delivered by the three major aqueducts was used in at least two distinct ways.[28] First, it was played directly on to the deposit itself in a continuous stream, in exactly the same way as ground sluices were used in the nineteenth century.[29] The stream has thus cut the numerous gullies in the northern half of the site, as already described. This type of work is known as *hydraulicing*, by analogy with the modern practice of mining metalliferous gravels and placer-deposits with jets provided by a head of water.[30] Secondly, the numerous smaller tanks on the south ridge were used in the practice of *hushing*, or the use of a wave of water released from a tank, as described by the Elder Pliny and discussed in App. I (p. 183), to remove waste overburden, a particular problem on the site of Las Medulas. The tanks are perched on the lip of the opencasts, in ideal positions to work the deposits below. Certainly the character of the gold deposit at Las Medulas excludes alternative uses, such as driving simple machinery. This probably did happen in the different geological circumstances of the Dolaucothi mine,[31] but at Las Medulas an efficient series of sluices would have been quite sufficient to process the auriferous effluvium from the hydraulicing.

From the evidence at present available, it is possible to suggest a three-period sequence with several sub-periods for the overall mine development. This does not, of course, take account of the earlier exploration or working at a lower level that is implied by the three lowest aqueducts (p. 175). (1) The south ridge being more directly accessible, working probably started at the western extremity, using the two aqueducts already described. Following exhaustion of this part of the deposit, the western hydraulic system was abandoned, and the middle part of the ridge attacked by means of a second set of tanks, thus isolating the earlier features. (2) A third aqueduct was constructed in the second period to attack the northern slope of the south ridge, not easily accessible from the other side, although small-scale working had perhaps been attempted. The same method of working back along the ridge appears to have been adopted, although ground sluicing rather than hushing was used. (3) The final period was probably the most difficult of all, because of the problem of providing a levelled water supply from the Cabrera valley. Since this was clearly impossible, a compromise was tried which involved tapping the aqueduct via the lower gulley (shown in pl. XX, a). At some stage attempts may have been made to construct a lower aqueduct, as is suggested by the discontinuous line that appears below the main aqueduct-level. Whatever the exact method, it became possible to attack the northern part of the site, where the provision of an adequate head of water was of great importance. For this reason reservoirs A and B are of a quite different scale and style compared with the smaller ones on the south ridge, and were partly designed, perhaps, to collect run-off rainwater.

From comparable data on hydraulicing operations elsewhere in the last century,[32] and the calculation of the amount of water delivered by the comparable Dolaucothi aqueduct,[33] it is possible to estimate a minimum time-span for each phase. The full details are reserved for an Appendix (pp. 184–5). The three opencasts that lie along the aqueduct line on the south slope of the south ridge took at least eighteen years to be excavated; the second period probably lasted no longer than a season or so, judging from the size of the accompanying gullies; the last period must have extended for a considerable time owing to the

[28] The Elder Pliny classifies such hydraulic gold-mines as *alutiae* in a passage relating to lead: '(plumbum) invenitur et in aurariis metallis quae alutias vocant', *NH* XXIV, 157.

[29] R. W. Paul, op. cit., 151 ff.

[30] Maclaren, op. cit., pl. 25.

[31] Lewis and Jones, loc. cit., 258.

[32] C. C. Longridge, *Gold and Tin Dredging* (1914), 233 f.

[33] G. D. B. Jones, 'The Dolaucothi Aqueduct', *Bull. Board of Celtic Stud.* XIX (1960), 71 ff.

different style of working. Earlier observers [34] who focussed attention on the main 'badland' area below tanks A and B (pl. XIX, a), suggested that the whole complex was an artificial creation. Yet no fossilized hydraulic features were found in the isolated masses, and this negative evidence points to a largely natural origin for this part of the site.

PUERTO DEL PALO

Description. The repetition of the name Montefurado was the clue to the location of another site that is even higher and rivals Las Medulas in its spectacular character.[35] The geology of the site is very different. It lies on the northern watershed of the Asturian mountains, amid the upper tributaries of the Rio Navia. One major tributary in Oviedo province is the Rio del Oro; it flows in a half-circle from the watershed known as the Puerto del Palo,

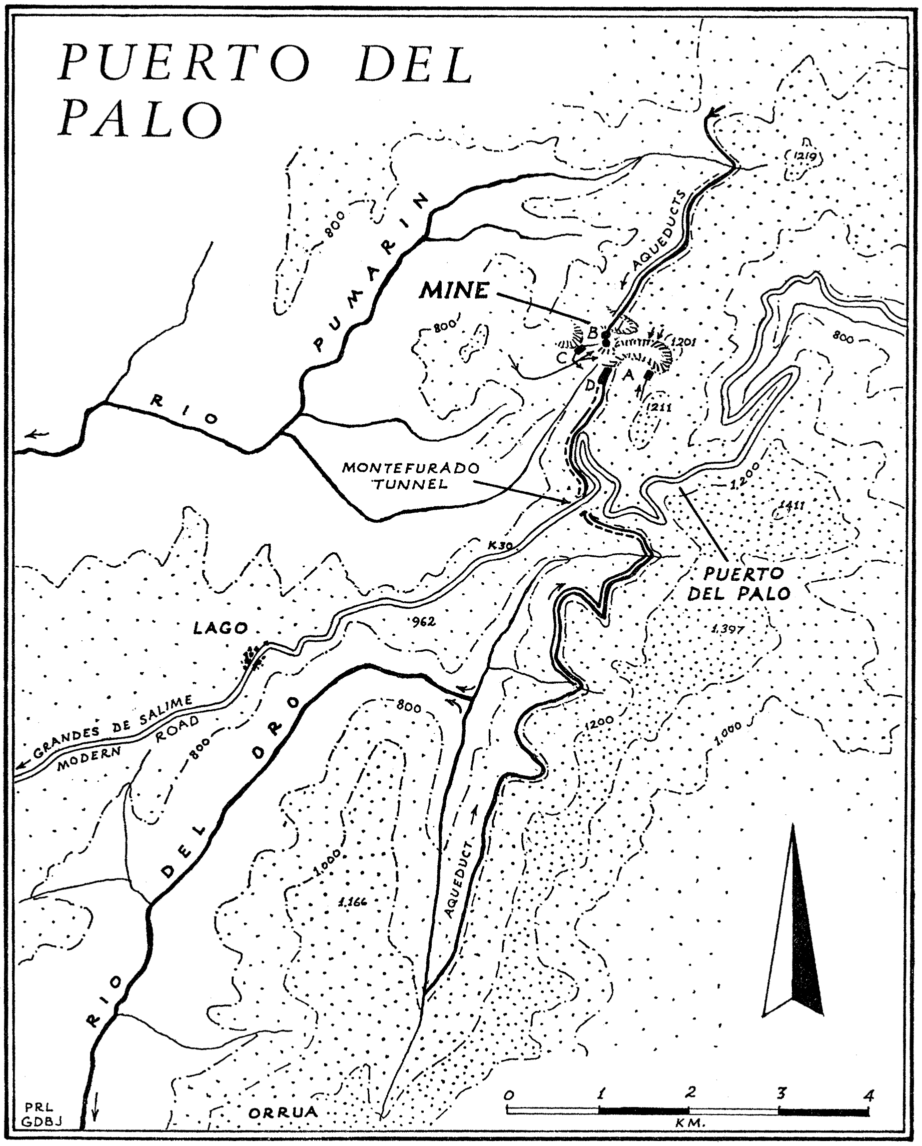


FIG. 26. GENERAL PLAN OF THE PUERTO DEL PALO MINE

Drawn by the authors. Copyright reserved

[34] Notably Longridge and Del Mar.
[35] The site was examined by the authors in the company of Mr. D. G. Bird, to whom we are grateful for comments and information.

which divides the river systems of the Navia and Narcea. Its name, Rio del Oro, is a possible indication of early mining, and there is a tradition of Roman activity in the valley.[36] On this score nothing can be now established, for both this tributary and the Navia valley have been flooded to form a reservoir. The modern route to Puerto del Palo climbs eastwards from the reservoir at Grandes de Salime reaching the 990 m ridge on which rests the small village of Lago, three kilometres short of the final ascent over the Puerto del Palo at *c.* 1,170 m. (fig. 26). At the foot of the final climb lies a feature traditionally known as Montefurado. As its name implies, it is a narrow tunnel cut through the ridge along which the present road approaches the pass. The small, level tunnel is surely an aqueduct channel rather than any kind of mine adit, and many parallels to it in size and function could be found amongst the *cuniculi* or aqueducts of the Roman campagna.[37] The Montefurado tunnel serves the lower of two aqueduct systems that can fairly be claimed to represent one of the most outstanding examples of hydrological engineering known in the Roman world. The headwaters of the Rio del Oro consist of two tributaries, flowing in from north and south in diametrically opposite directions, presumably along the line of a geological fault (fig. 26). The southern branch, running from the peak known as Orrua, is the highest substantial stream in the Navia–Narcea watershed, rising at an altitude of over 1,200 m. The major aqueduct (pl. XXII, b) tapped the headwaters of this southern tributary and, passing over the ridge of the Montefurado tunnel, carried a head of water from the Rio del Oro valley on to the western flank of the Sierra del Palo. The minor aqueduct flowed through the Montefurado tunnel, following a parallel but shorter course at a level of about 20 m lower. The tributaries of the Rio Pumarin on the western side of the mountain only reach a height of 900 m. So carefully engineered an aqueduct system, which tapped the water from one river valley and passed it into another, must have been designed to serve a mine at the 1,000–1,100 m level, i.e. at too great a height to be served by the Rio Pumarin system.

The mine itself, which is to be associated with the traditional name of Cueva de Juan Rata,[38] can be located by the white mark of a vertically bedded quartz outcrop at the north-western tip of the Sierra del Palo. In geological terms, it probably forms part of a north–south strike of the primary quartz outcrop that runs across the Asturian mountains. Another such outcrop can be seen at about the same height of 1,000 m over 12 km to the south-east. The mine itself consists of a major opencast and a minor one immediately to the north. Past its foot there ran another aqueduct, flowing southwards from the highest branch of the Rio Pumarin. It appears to be smaller in scale than the Rio del Oro aqueducts, but more detailed work is required before a definite description can be given.

The main opencast is so massive in scale that there is an initial temptation to dismiss the site as a natural formation (pl. XXII, a). But the presence of an exceptionally well-preserved hushing-tank (A), just beneath the southern summit of the opencast (pl. XXIII, b) makes this impossible. The opencast proper measures just over 200 m vertically. While the floor of the lower part has been covered by a deposit of silted material (pl. XXII, c), the upper half is a nearly vertical wall of highly-weathered quartz that reaches up to the summit of the mountain ridge, the rock becoming somewhat looser on the southern side. It is there that the hushing tank (A) is located, 55 m long by 5 m wide, with the walls standing over 3·5 m high. The profile of the tank has been exceptionally well-preserved, since the altitude ensures a thin vegetation (the top of the mine area is under snow throughout the winter months) and a lack of erosion (pl. XXIII, b). The tank is set back *c.* 15 m from the present edge of the opencast, and its outfall shows a clearly preserved two-phase sequence. At first the outflow was channelled downhill through a V-shaped sluice (pl. XXIII, c); when this was abandoned, the head of the channel was blocked and another massive sluice cut in an arc on the edge of the opencast. The tank is thus a classic example of hushing or hydraulicing from the head of an opencast, a principle implicit in the Elder Pliny's account of mining (App. I) and first attested by Tank G in the Dolaucothi mine. Further down the southern flank of the opencast, below the tank, there are further uncertain indications of mining activity that include a stepped washing table, served either

[36] *Mining Journal* (8/2/1896), 199.

[37] G. D. B. Jones, *PBSR* XXXI (1963), 140 f., cf. 74–99. For the background, see T. Ashby, *The Aqueducts of Ancient Rome* (1932).

[38] O'Reilly, op. cit., 65.

by the first-phase downfall from the tank, or by a second small aqueduct running back along the mountainside. To the north, on the opposite side of the opencast, there are traces in the scrub of the ledges carrying two further leets towards the lip of the mine. If they originally fed tanks, then these have been eroded away. Towards the foot of the slope there is the bowl of the minor opencast. The Pumarin aqueduct, which appears to be double-channelled in its final stages, ran across the lower bowl of the opencast just as the Cothi aqueduct at Dolaucothi traversed an earlier opencast.[39] It then delivered into a double reservoir (B), seen from above in pl. XXII, c. This had two functions : first, it supplied water to the northern foot of the main opencast (by contrast the final stages of the Montefurado aqueduct, including much of the terminal reservoir, have been eroded away) ; and secondly, it carried an extension of the aqueduct system on to the western spur, where a third tank (C) suggests a northward-facing opencast. A particular interest attaches to the continuation of the aqueduct system beyond this last-mentioned tank. It was carried in a deep trough (pl. XXIII, a) a further 75 m or so along the scarp, and then turned through a ninety-degree angle to discharge directly down the mountainside to the valley floor (fig. 26). Its channel is still crisply preserved, without significant signs of lateral erosion, thus indicating a very brief period of use. The strike of the main quartz outcrop might, if projected, reasonably be expected to reappear at this point on the mountainside though in fact this is not the case. The likeliest explanation of the feature, therefore, is that it represents a prospecting gully that drew a blank.

The gully must have been preceded by another aqueduct, also visible on the hillside (pl. XXIII, a). It ran eastwards along the western ridge, and appears to have divided in two close to the foot of the mine (fig. 26). Its potential head of water was limited owing to its position, and it is best viewed as an early attempt, discarded after the major aqueducts were built.

Analysis. Puerto del Palo, as suggested in the introduction, is an example of a hard-rock mine designed to attack primary quartz deposits, and at a greater altitude than either of the other two gold-mines. The exploitation of such mines is critically affected by the problem of water supply. The site lies at the southern end of an area that, in its geological form, is probably a dissected dome that contains the sources of several river-systems. The height of the Puerto mine, however, was too great for any of the local streams to yield a continuous supply. In the first instance, the short aqueducts draining the surrounding spurs must have been utilized. Nor should one underestimate their yield, which could have been considerable after the melting of the winter snows ; and the snow-falls from late October to April would in any case make mining a seasonal operation. Nonetheless, the aqueduct system was extended by a remarkable hydraulic system which tapped the southern headwaters of the Rio del Oro (fig. 26). General probability suggests that the smaller aqueduct of the two using the Montefurado tunnel—whether deliberately planned or a mistake in levelling—was the earlier. To it was added the larger, second aqueduct on a slightly higher line, which took the same principle to its furthest point by tapping the main stream yet further south on the slopes of the Orrua.

Only one adit is visible on the site itself, an important point that implies that the greater part of the extraction process must have been conducted by hydraulic means. Tank A is a classic example of its kind, perched at the head of the main opencast ; it shows us how hydraulic mining could proceed along the lines described by Pliny (App. I), and the melting snows and autumn rains at this height (1,200 m) would provide a sufficient head of water at least for seasonal operation. The discovery of several leets on the northern side of the opencast implies the existence of other such tanks that have possibly been eroded or mined away. Lower down on the north side the development of the minor opencast occurred relatively early, because the northern aqueduct can be traced crossing the bowl of the opencast. The development of this hydraulic system, tapping the various streams rising from the dissected dome to the north, now made it possible to explore the western ridge below the main mine, where tank C was used to work a probable opencast to the north and explore any continuation of the quartz deposit by means of hushing along the

[39] Lewis and Jones, op. cit., 259.

southern slope. Such was the general framework, and such the basic stages of the development of the Puerto del Palo mine.

CONCLUSION

Of the many problems presented by ancient mining sites, attention may be drawn to three in particular. These are, first, the determination of the origin and development of the site in question; second, the techniques used to extract the ore; and last the character of the associated social and economic organization. Partial answers to these problems may be obtained by exploratory fieldwork, if we bear in mind the peculiar nature and large scale of the features normally present at mining sites.[40] Selective excavation may then clarify various aspects of the site, as has been done in the second-stage programme at the Dolaucothi mine in Britain, wherein excavation was used to test the most probable hypotheses suggested by fieldwork, largely in relation to hydraulics, and it became possible to build up a more detailed picture of the mining techniques employed.[41]

An heuristic approach to important sites remains an essential first step in a rigorous study of Roman and ancient mining. More extensive exploitation of other sites in north-western Spain, for instance, will undoubtedly focus attention on detailed problems within the threefold division discussed above. We may wish to determine, for example, how quickly the sites were developed following the conquest of the region, and how long it took for the particular deposits to be exhausted. While a rough estimate can be made from the calculations set out in App. II, further evidence is clearly needed. A related problem concerns the extent to which the principal gold-bearing deposits were exploited before the conquest, and what techniques were employed. *A priori* one might expect the easier placer-deposits to have been exploited during the prehistoric period, and their existence undoubtedly would have initiated Roman interest in the area. Such might have been the case at Montefurado, but seems very unlikely at the difficult high-level mines worked at Las Medulas; this site could only have been exploited with the use of large-scale hydraulic techniques depending on aqueducts, since the height of the deposit excludes any working-technique using rivers or streams directly. By analogy, at Dolaucothi it was possible to suggest that in prehistoric times a small-scale attack on the vein-system stimulated extensive Roman exploitation; the use of exploratory hushing (*v.* App. I, below), however, exposed other and possibly richer ore-bodies close by, and it was around these that the main development occurred.[42] The pre-Roman working areas thus became obsolescent owing to the introduction of a much more efficient technology. In Spain, the essential preliminary to any estimate of the extent of pre-Roman gold-working must be an adequate distribution-map of the hill-forts on which pre-Roman settlement was based, as a pointer not only to the likeliest areas of pre-Roman placer-working, but also to a solution of some of the topographical problems still awaiting explanation in the course of the Augustan conquest.[43]

APPENDIX I: THE ELDER PLINY AND GOLD-MINING

While prehistorians often view evidence from a technological standpoint, Roman archaeologists, with an embarrassment of material remains to assimilate against an historical background, tend to pay only lip-service to the giant technological strides that were made in the period. There is a tendency in recent years to take the massive achievements of Roman technology—dams, bridges, aqueducts and mines—for granted without bringing the details into focus. This partly reflects the silence of the literary sources on subjects relating to technology. One notable exception is the Elder Pliny who in *NH* XXXIII, 67–78 gives an account of gold-mining that is clearly much influenced by informa-

[40] For the kind of problems concerned, i.e. the geomorphological effect of human agency in the classical period, v. C. Vita-Finzi, *Mediterranean Valleys* (1969), *passim.*

[41] G. D. B. Jones and P. R. Lewis, *Ant. J.*, forthcoming.

[42] Lewis and Jones, op. cit. 246.

[43] The authors would like to acknowledge help from many sources in Spain and Britain: Dr. A. P. Masiá and Prof. A. G. Alvarez of the Consejo Superior de Investigaciones Cientificas; Prof. Almagro and Dr. Figuerello of Madrid University and the Cultural Attaché of the Spanish Embassy; Mrs. V. A. Jones, Dr. J. P. Wild, Mr. D. G. Bird and the Needham Hall Fund of Manchester University; and the Society of Antiquaries of London for access to the Gowland Bequest. The authors are deeply grateful to Sir William Mansfield-Cooper, formerly Vice-Chancellor of Manchester University, and to the Dept. of History in the same university for subventions towards the cost of travel.

tion from Spain, although the actual source is not known.[44] The account is therefore of particular interest in the context of this article. Despite a few errors, Pliny's text can be analysed as a commentary on Roman mining practice in general and is particularly valuable for its emphasis on the role of water power, not merely for washing but also hydraulicing and hushing, the latter practice now being confirmed from archaeological evidence at the Dolaucothi gold mine in South Wales. No translation currently available takes account of standard mining practice or terminology; so the following somewhat free translation is offered with a parallel commentary that draws on comparative material from nineteenth-century sources.

Text of NH xxxiii, 67 ff.	*Comment*
67. ' Gold prospectors begin by collecting *segullum*, that is placer-deposits indicating the presence of vein gold. After the auriferous material is washed, the sediment allows an estimate of the actual vein to be made . . . Gold found by this method is called *talutium*, a term that covers placer-deposits in general. It is, in fact, the wealth of placer-deposits that brings prosperity to the dry, barren mountains of the Spanish provinces.	This is the commonest form of prospection, i.e. tracing vein gold from derivative placer-deposits, cf. Westgarth Forster, *A Treatise on a Section of the Strata from Newcastle-upon-Tyne to Cross Fell* (3rd. ed., Newcastle, 1883), 161 ff. (hereafter Forster). Placer-mines were not, of course, the only source of gold in Spain. Montefurado, for instance, was both a vein and placer mine (pp. 173–4).
68. ' Vein gold may be obtained by underground or opencast working. It can be found in a crystalline matrix . . . Traces of the veins appear here and there along the walls of the underground galleries and the overburden is supported by wooden props.	Distinction between opencast and underground working. Geological occurrence of gold.
69. ' The mineral extract is crushed, washed, fired, and ground to a fine powder. Ground ore is called *scudes*, the molten metal, when tapped, the *sudor* (= " sweat ").	Smelting.
Whatever the metal in question, the molten waste is called *scoria* or slag. In the case of gold, however, the *scoria* can be crushed and fired again. Crucibles are made of *tasconium*, a white fire-clay. This alone can withstand the forced draught and intense heat of both furnace and molten metal.	The refinement of smelting methods would suggest reworking of slag. Such a process was noticed by Charles Darwin during exploration of Chile, *Journal during the Voyage of H.M.S. Beagle around the World*, 193 ff., *v.* Lewis and Jones, *Ant. J.* XLIX, ii (1970), 253, n. 4.
70. ' The third gold-extraction method rivals the projects of the legendary race of Giants. By the light of lamps long galleries are excavated into the mountain. The lamps measure the shifts, and the men may not see daylight for months on end.	The two other methods are placer and opencast mining.
This class of mine is termed *arrugiae*. In them sudden collapse can crush the miners, so that diving for pearls or dyes now seems a safer job—so much has mining been made a more hazardous occupation. As a protection the overburden is supported by rock	A general description of deep mining.
71. arches at frequent intervals. Whatever the underground mining methods employed, hard quartzite masses will be encountered. These can be split with the help of firesetting involving use of acid. More often firesetting in adits makes them too hot and smoky; instead, the rock is split by crushing machines incorporating 150 lb. iron weights. The miners then carry the ore out on their shoulders, each man forming part of a human chain working in the dark, only those at the end seeing the daylight. If the quartzite seems too large a mass, the miners divert the drive to go round it.	This seems to be a description of underground stoping of ore-bodies. For firesetting at Dolaucothi, *v.* Lewis and Jones, *Ant. J.* XLIX, II (1970), 256.

[44] The source may be personal knowledge. For a discussion of the Elder Pliny's career in Spain, v. R. Syme, ' Pliny the Procurator ', *Harv. Stud. Class. Phil.* LXXVIII (1969), 218 ff.

72. 'Yet rock of this kind is considered relatively easy in comparison with *gangadia*, a form of conglomerate, that is almost insuperable.

This is not easy to interpret, as a conglomerate rock should not present such difficulty.

'The method used in this case is to attack it with iron wedges and the crushing machine mentioned above. *Gangadia* is considered the hardest of things except the greed for gold which is the stubbornest of all. When the work is completed the miners cut away the roof props, beginning with the last. A crack, seen only by a watchman perched on the slope
73. above, is the prelude to the collapse. With a shout or wave he orders the miners away and leaps for safety. The overburden falls apart as it collapses with an incredible crash and blast of air. Like conquering heroes the miners comtemplate their triumph over nature. Yet even at this stage no gold is apparent nor did they know of its positive existence when they began to dig. Mere hope was sufficient inducement to counterbalance the danger and the costly processes involved.

From the mention of the watchman it appears that this is not a description of mining underground galleries at deep levels, but of the creation of adits that are collapsed in the early stages of an opencast.

A modification of this method would explain the development of the opencast at Montefurado.

74. 'Equally laborious and more expensive is the associated problem of running aqueducts mile after mile along mountain ridges to wash away mining debris. The aqueduct channels are called *corrugi*, a term derived from the word *conrivatio* or confluence. The problems are innumerable; the incline must be steep to produce a surge rather than a trickle of water; consequently high-level sources are required. Gorges and crevasses are bridged by viaducts. Elsewhere protruding rocks are cut away to allow the placing of flumes.
75. 'Workmen cutting the rock face are suspended on ropes so that from afar they look not so much like a herd of strange animals as a flock of birds. Usually the men are suspended to level the projected route; man thus brings water through places where he himself cannot pass.

Pliny now turns to hydraulics.

This would imply the process of hushing, see *Note* below.

Reference to the aqueducts serving Las Medulas (pp. 174–6) shows that this description may not be as rhetorical as it first appears. The initial stages of the Cothi aqueduct serving the Dolaucothi mines must have been cut by this method. Jones *et alii*, *Bulletin of the Board of Celtic Studies* XIX (1960), 77 ff.
For the other Dolaucothi mine-aqueduct, *v.* Lewis and Jones, 'The Annell Aqueduct', *Britannia* II, forthcoming.

'The washing process is ruined if the water is full of silt or *urium* as this is called. To avoid this the water is made to flow over gravel or pebbles. On the ridge above the minehead, reservoirs are built measuring 200 ft. each way and ten feet deep. Five sluices about a yard across occur in the walls. When the reservoir is full, the sluices are knocked open so that the violent downrush is sufficient to sweep away rock debris.

Washing. This passage may seem to contradict Pliny's earlier comment about the incline of the aqueduct, but two separate processes are involved. Tanks of this kind are known not only at Las Medulas, at La Leitosa, Paradaseca (= No. 3 in fig. 23), and Puerto del Palo (Tank A), but also at Dolaucothi, (Tank G). *v.* Lewis and Jones, *Ant. J.* XLIX (1970), fig. 6, and p. 266. The explicit reference to the removal of rock debris makes it clear that Pliny is describing *hushing*.

Note. The application of this technique, both as a means of prospecting and of clearing rock debris, has been doubted by some who are unaware that the process was extensively used in this country and elsewhere, even on sites with heavy top-soils, during the last century. In particular, Forster's descriptions (o.c. 164–5) are worth quoting extensively to correct some present misconceptions:

'When float, or shoad, ore is found in a small flat spot in the middle, or near the bottom, of a sloping piece of ground, *hushing* is a very good method of securing it. Where circumstances are favourable for it, this is undoubtedly the most effectual, and, at the same time, the most economical method of trial. There should be a slope of considerable declivity and there should also be a suitable place for making a dam head, or reservoir, for collecting water; the more elevated the dam the better it will be.... The dam should be made upon the slope of the declivity in the form of a half-circle....

Where the ground which is to be hushed is of any considerable length, the reservoir must contain a considerable quantity of water, otherwise its force will be spent too soon and will prove ineffectual for carrying down to the bottom of the soil, earth etc. . . . It is necessary to observe that the breast of this reservoir should be strong in proportion to the quantity of water we wish to collect, and that a sluice of necessary strength be used.

'The writer has seen stones of several tons weight, and as big as little huts, carried several hundred yards down a large hush-gutter. The torrent and the rush of stones wear out, not only the surface and the soil, but also a considerable depth of the superficies of the rock itself, and thus they discover and wash clean all the veins.' (For the confirmation of this evidence, cf. C. S. Fox, *The Geology of Water Supply* (London, 1949), pls. xviii and xix, facing p. 119.)

76. 'Another task awaits on level ground. Water conduits, the Greek name for which means "leads", are cut in steps and floored with gorse, a plant resembling rosemary, that collects gold particles. The conduits are boarded with planks and carried over steep pitches. Thus the tailings flow down to the sea and the mountain is washed away.

Washing. Pliny conflates two varieties of washing processes: (i) stepped washing-tables cut in the ground, preferably rock, as found between Tanks C and E at Dolaucothi (Lewis and Jones, o.c., 258); and (ii) wooden washing-tables with boarded sides, generally termed 'Long Toms' in nineteenth-century miners' parlance, especially in California. The systems could in fact be confused with the washing-tables (or more elaborate variations, called riffle-boxes, set in a stepped series). For these and other comparable nineteenth-century developments, R. W. Paul, *California Gold: The Beginning of Mining in the Far West* (Univ. Nebraska, 1947), 151 ff.

It is because of this that currently the Spanish land mass has encroached a long way into the sea.

This is a confusion with the normal processes of silting that create delta fans, etc.

77. 'Gold mined in *arrugiae* does not require smelting but represents pure gold. Nuggets are found in deep mining and also in pits, some weighing more than ten pounds. They are called *palagae* or *palacurnae;* gold dust is called *baluce*. The gorse is dried and burnt and its ash is washed on a bed of turf sods, so that the gold is collected.

This is incorrect, being perhaps a confusion with nuggets found in placer deposits: see below. The reference to pits relates to small-scale working of placer or surface deposits.

Another reference to washing. This second method is comparable with the use of gorse in § 76. Why the process is repeated remains obscure.

78. 'According to some sources Asturia, Galicia and Lusitania produce twenty thousand pounds weight of gold in a year, the former supplying the largest amount. Spain has long been the main gold-producing area. By an old senatorial decree Italy was protected from over-exploitation, for otherwise it would have been the most productive area, as it is in agricultural produce. An extant decree of the censors concerning Victumulae near Vercellae prohibits *publicani* from employing more than five thousand men in mining.'

Direct comparisons with Roman production figures are difficult because nineteenth-century operations were almost exclusively in placer-mines. An 1855 pamphlet estimated the gold-production of North-West Spain at 35,000–40,000 *duros* per annum. Towards the end of the nineteenth century the *duro* was worth approx. three shillings at the exchange rate of the time: O'Reilly, *Proc. R. Irish Acad.* xx (1900–1), 61; cf. *Mining Journal*, Feb. 8th., 1896, 171.

Restrictive trade practices are rarely known to us from the Roman empire. Another example is possibly to be found in the limitation on British tin production in favour of Spain in the first two centuries A.D. The resurgence of Cornish tin-mining in the third and fourth centuries is otherwise hard to explain.

APPENDIX II: ESTIMATES OF THE TIME-SPAN IN OPENCAST WORKING

It is possible to estimate the lifetime of particular opencasts from a knowledge of three factors: the amount of material removed from the opencast, the volume of water delivered by the aqueducts concerned, and the volume of water needed to hydraulice a unit volume of auriferous gravel. The first factor can be roughly estimated from the size of each opencast (fig. 25), and their dimensions are shown in the tables below: it has been assumed that the opencasts may be represented by a triangular or rectangular box as is more appropriate in each case. The third and fourth columns give the volume of material removed in millions of cubic metres (V) and the estimated amount of water delivered per day (H). The figure of 2·5 million gals. per day comes from an earlier calculation for an aqueduct of similar size at Dolaucothi, South Wales.[45] The life-spans of the opencasts (T), shown in the last column, have been calculated from the formula:

$$T = \frac{8{\cdot}7\,V}{H}$$

The constant has been calculated using information supplied by Longridge,[46] first that 25 cubic feet of auriferous gravel weighs one ton and second that 12·5 tons of water (i.e. 2,800 gals.) are needed to remove one ton of material.

Period	Opencast dimensions (metres)	Volume removed (millions of cu. ms.)	Water delivered per day (gals.)	$T = \frac{8{\cdot}7\,V}{H}$ (Years)
I. a	$\frac{1}{2} \times 500 \times 500 \times 60$	7·5		13
b	$300 \times 300 \times 30$	2·7	*c.* 5×10^6	5
c	$100 \times 50 \times 20$	0·1		2 months
II. a, b	—	?	$2{\cdot}5 \times 10^6$	A year or two ?
III.	?	?	$2{\cdot}5 \times 10^6$	Decades ?

The uncertainties of using such a simple argument are manifold but may all be expected to increase, rather than contract, the time-span. The dimensions are no more than rough estimates, neglecting subsequent natural erosion, which should be relatively small across the 2,000-year span, but the most important source of error concerns the hydraulicing equivalent of 12·5 tons of water for every ton of material. This estimate is based on water supplied at a high-velocity by modern pumps, and an equivalent figure for a relatively slow-moving stream is not available. It may increase the expected lifetime by a factor of two, if not more. It has also been assumed that the water flow was continuous over the given time-span but one might expect seasonal factors such as the freezing of streams at the head of the aqueduct, for example, to affect consumption. Nonetheless, if the subject is to be further refined, it seems worth attempting (with these provisos) the first assessment of the life span of a Roman opencast working.

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45 G. D. B. Jones, *Bull. Board of Celtic Studies* XIX (1960), 71 ff. For a similar attempt to calculate flow in a closed aqueduct v. G. D. B. Jones, *PBSR* XXX (1962), 200 f.

46 C. C. Longridge, *Gold and Tin Dredging* (1914).