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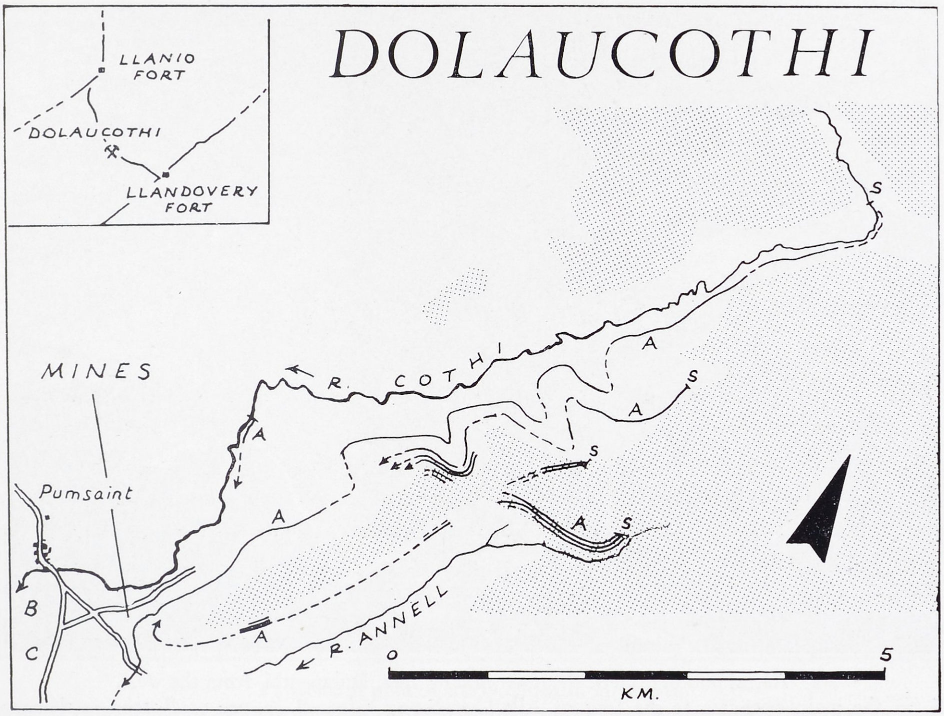
The Dolaucothi Gold-Mines

With the exception of the Elder Pliny very few Roman writers took an interest in the achievements of their own technology. Yet it is probably the massive visible remains of that technology – in the form of dams, bridges, aqueducts and harbours – that first spring to mind when Roman achievement is mentioned to the layman. Yet nowadays archaeologists tend to take the enormous volume of background material for granted without exploiting the detailed information available to bring the foreground into focus. The Roman gold-mines at Dolaucothi, near Pumsaint, in Carmarthenshire, are a case in point. They have long remained a site of unique potential yet, apart from the recent survey of the elaborately engineered aqueduct that carried several million gallons to the minehead every day, descriptions of the site proper have often been based on generalisations with little or no basis, particularly where questions of mining technology are involved. To rectify this situation the Dolaucothi Research Committee of the National Museum of Wales has recently been formed to launch a programme of field-work, excavation and underground exploration over the next few years. This note is designed to outline the main result of the first two season's work made possible by the generosity of the University of Manchester and the Society of Antiquaries. The principal purpose of the excavation was twofold; to confirm the existence of features identified on the ground and then to relate the corpus of evidence to the problems of Roman mining technology as exemplified on the site. This involves above all questions of hydrology and the aqueduct systems emerge, in many ways, as the key features of the site. The results must, therefore, be treated as an amalgam of both fieldwork and excavation involving the whole site, not simply the main opencast which, it is now clear, represents only a late phase of Roman exploitation.

Strategy (fig. 1–3)

In bare outline the Dolaucothi complex comprises three features:

1. Two Aqueduct Systems: a 7¼ mile aqueduct from the headwaters of the Cothi that runs along the northern slope of Allt Cwmhenog and serves a series of reservoirs and sluices before turning south to discharge into the valley of the Annell below Caio. Second, a smaller aqueduct tapping the head of the River Annell and running 4½ miles to the minehead at a level ca. 39 m above the Cothi aqueduct to serve the Area I working (fig. 2.3).

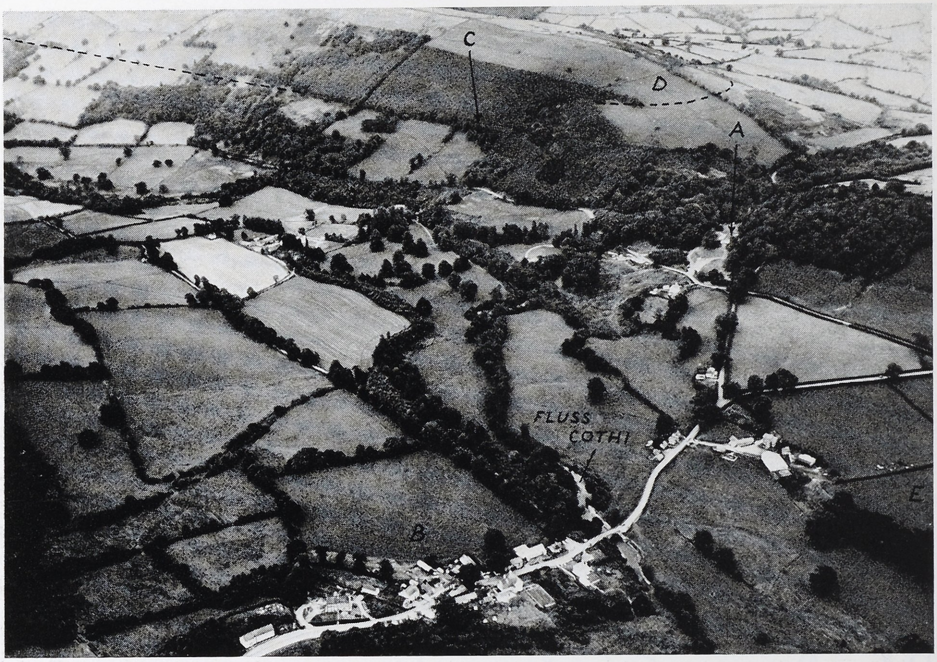


1 General plan of the Dolaucothi mining area. – Scale 1 : 75000.
A = Aqueduct. – B = Roman baths. – C = Cemetery area. – S = Aqueduct source. – Stippled area over 305 m.

2. Opencast workings and adits along the northern slopes of Allt Cwmhenog, Allt Ogofau and the col that separates them; of the workings by far the largest is the main opencast immediately south of Ogofau Lodge. From the survival of conduits and water tanks along the edge of the opencast it appears to have preserved substantially its Roman shape through the periods of modern mineral exploitation. The last of these in 1937–38 located traces of Roman galleries (from one of which part of a timber drainage wheel was recovered) to a depth of 45 m. below the floor of the opencast.

3. The associated features in the floor of the Cothi valley which include a substantial settlement beneath Pumsaint village and a bath-house on the south side of the river.

Superficially the starting point for any survey might appear to lie in the underground adits that have consistently stolen the limelight from the remarkably preserved features around and above the main opencast. We suggest, however, that surface examination of the site yields more interesting and useful data relevant to the complex history of mineral exploitation. The problems may be taken as, first, the origin and development of the mine and second, the way in which the ore was won and exploited. A third question, the socio-economic character of the associated settlement in and around Pumsaint village, does not concern us here. The prime evidence for the first two questions lies in the easily

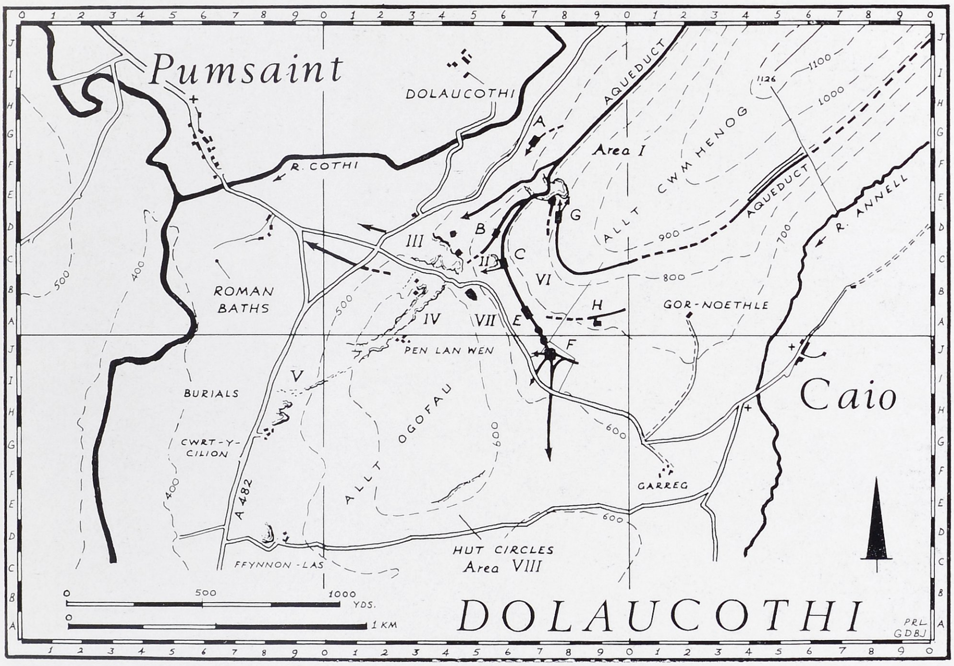


2 Aerial photograph of the main mining area, Dolaucothi, from the west. A = the main opencast at the foot of Allt Cwmhenog ridge; B = site of Roman settlement beneath the present village of Pumsaint; C = level of Cothi aqueduct; D = level of Annell aqueduct; E = site of Roman baths.

accessible but complex surface features of the mining areas. This may seem obvious to an outsider but it critically affects the archaeological strategy best adopted. The underground workings below the main opencast have been made largely inaccessible through flooding (they extend to a known depth of ca. 45 m below the present opencast floor) but some survive between Area II and the opencast proper. These are currently being investigated by the Department of Mineral Exploitation, University College Cardiff and the results will illustrate the final stage of the mine development. Although important in their own right the results must be seen in the context of the overall mining sequence because, as can be seen from fig. 8 it is clear that the underground workings represent only the ultimate phase of Roman exploitation.

Ground and Air Survey (fig. 1–4)

Most of the area has now been examined in detail on the ground. Whether the settlement underlying the Pumsaint village is military or civil in character, it has now yielded (from the eroded bank of the Cothi) samian ware of Flavian date to show that Roman exploitation follows immediately upon the conquest ca. A. D. 75. Such speedy mineral exploitation already has its parallels from the Mendip and Flintshire mines. To the south the terrace between the main opencast and the Cothi has also yielded information. Ground quartz can be found after ploughing



3 General plan of the Dolaucothi mine area.
The Roman numerals refer to mining areas, the letters to tanks and reservoirs. Contours in feet.

and circular patterns visible from the air may indicate the presence of cupels or crushing circles known as 'trapiche'.

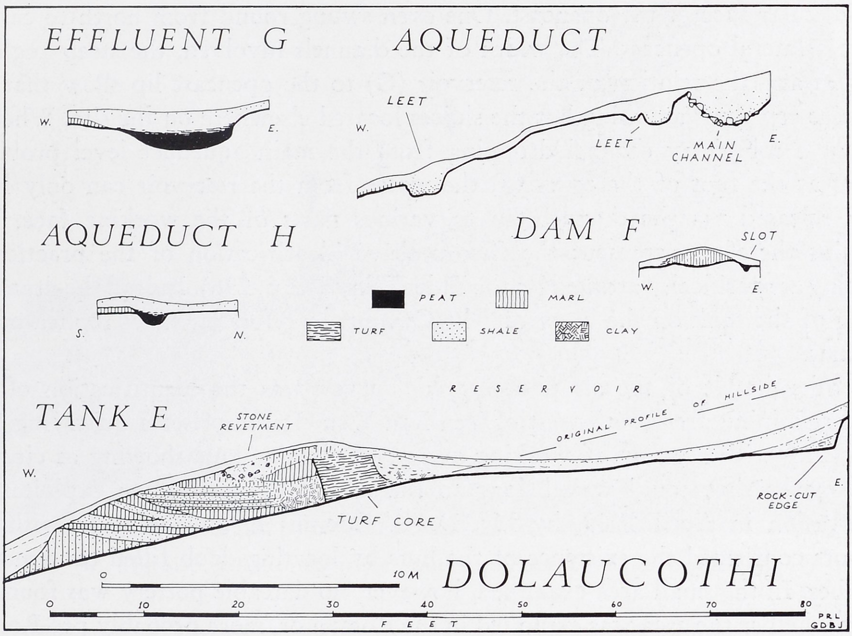
Fieldwork in the mine area was greatly helped by the late spring of 1968. The reduced vegetation revealed the presence of a substantial reservoir (ca. 24 x 12 m = tank A on fig. 3) perched on the hillside north of Area I. The tank supplied a head of water to the working area below this opencast that now lies in the heart of a forestry plantation; it could also have been used to attack placer deposits along the edge of the valley floor. On the main aqueduct level east of Area I the channel divided into two branches, the lower running to a small reservoir (B) again obscured by the present forestry plantation. Up to this point the water flow was maintained at a very slight incline; from tank B the effluent channel, rock-cut in several sections, then dropped at a steep gradient to the area above the main opencast. Tips from the Mitchell Mine have destroyed much of its lower course but it must have supplied two small tanks still preserved immediately above the lip of the opencast. The former is rock-cut with vertical sides and was fed by a rock-cut aqueduct channel that has survived intact.

The upper branch of the aqueduct represents the known line across the western edge of Allt Cwmhenog through tank C, sluice-way and tank E, the largest reservoir of the whole system (fig. 5). From this height the water was allowed to drop at speed along a rock-cut channel, that might mark a suitable point for the location of an undershot wheel, and so into the main effluent via the overflow from reservoir F. The existence of this reservoir was in part suggested by the

4 The line of the Annell aqueducts (arrowed) at the head of the Annell valley as seen from the east. The line of the Cothi aqueduct runs along the far side of the middle ridge to the minehead.

discovery of another water supply in the form of a conduit tapping an unnamed stream to the south-east. At times this extra supply must not have-been required because a diversionary channel at the lower end could transfer water directly into the main outfall. The actual reservoir was evidently designed to supply workings in the Melin-y-Milwyr area by means of at least two channels. The main effluent can be traced south across the Pumsaint-Caio road in the form of a reed-choked depression ca. 3 m wide marked in places by an earthen bank on the lower side.

So much for the immediate neighbourhood of the mines. In August 1968 the authors carried out an air photographic survey of the Dolaucothi area that in combination with further fieldwork added two fresh dimensions to the mining complex (fig. 3). First was the discovery of a second aqueduct system tapping the River Annell about $4^1/_4$ miles upstream at a height of nearly 395 m (SN 705425). Although much of the middle course of the aqueduct has been destroyed by a forestry plantation, elsewhere the aqueduct survives complete with detail that is unique of its kind in the British Isles. At the head, the various collection channels unite into a single specus close to the remains of a structure that appears to have formed a shelter or maintenance hut. It was a rectangular half-timbered building 6,4 m long by 3,2 m wide with traces of internal divisions and benches or stalls



5 Excavations of the hydraulic features (left to right): Section across effluent channel below dam F. – Section across main Cothi aqueduct between tanks C and E. – Section through supplementary aqueduct to tank F. – Section through dam F. – Section through tank E. – Scale 1 : 250.

at the southern end (fig. 8). The dwarf wall was carefully laid in slate blocks and cavities in it marked the points where timber uprights had been set. The vertical infilling was not in wattle and daub but in stacked turf blocks approximately one foot square. Down the line of the aqueduct, which is rock-cut at several points, there is clear evidence of alternative channels being created by repair work and a collection tank built round a spring to provide an additional head of water. Indeed the demand for water must at one stage (see below, p. 298) have been acute, because near the minehead above Gor-noethle Farm two additional channels, visible on the ground and confirmed by excavation, ran side by side with the lower main channel. This is the first example of a triple aqueduct known in this country (fig. 6).

The onward course of the aqueduct has largely disappeared but was visible twenty years ago and can still be traced from the air. It swings round the end of Allt Cwmhenog towards the head of the Area I opencast at a height of 813 ft., that is 39 m above the Cothi aqueduct traversing the opencast at a lower level. The Annell aqueduct fed twin reservoirs (G), the larger measuring 27,5 x 12 m, the smaller slightly less, now obscured by a forestry plantation on the brow above the opencast. The tanks were partially formed by cutting back the hillside and the outside wall still reaches a height of over eight feet. From the outfall two deep irregular channels plunge down to the head of the opencast 35 m away, to divide again into at least eight lesser channels that fed various points around the semicircular face of the opencast. One even swung round from north to east to serve a lateral opencast. The width of the channels involved, the steep angle of descent and the relation of the reservoir (G) to the opencast lip show that the remains represent anything but the sluices located elsewhere on the site. Whether or not a subsidiary channel dropping from the main aqueduct level provided water at the foot of the opencast, the water from the reservoir can only have been released via the channels on to various parts of the working face. The remains therefore represent the first positive identification of the practice of hushing as specifically attested by the Elder Pliny (see p. 296). Indeed the dramatic siting of the tank on the brow of Allt Cwmhenog offers an exact replica of his account.

The other result of the air photographic survey was the identification of yet another mining area south-west of Pen Lan Wen. It comprises a quarrying face associated with a group of working areas and circular huts showing as circular crop-marks that could well belong to the period of pre-Roman exploitation. Excavation in April 1969, by Mr. D. G. Coombs in collaboration with the authors confirmed the existence of the huts by locating daub filled construction trenches. In the small area examined, however, no dateable pottery was found to show whether the area was exploited in the Roman or, more probably pre-Roman period.

Excavation (fig. 5)

A programme of excavation in 1968 and 1969 was designed to examine the structure of the features at the end of the aqueduct and test, in all cases with positive results, the channels and tanks identified by ground survey. Amongst the latter, principal attention was directed to tanks C and E. The wall of C (ca. 24 x 6 m overall) had survived to 2,4 m in places and originally measured 7,9 m across. The section showed that it was largely built of laminated clay and shale, thus nullifying any suggestion that the remains simply represent mining dump. On the inside edge of the retaining wall a waterproof clay revetment 10 1/2 ft. thick had been bedded in the trench cut in the bedrock. It was strengthened horizontally by turf layers and stiffened at the front by a timber beam. A slot to house timber shuttering completed the inner edge of the tank. While this section is of structural interest, more importance attaches to the history of the tank. It is argued elsewhere (p. 295) that many of the tanks associated with the aqueduct system would have undergone changes in the role or roles as the mining sequence developed. This is apparent from the area below tank C, where one can see with the help of low vegetation that a rock-cut outflow channel was replaced by a stepped washing table running at a slightly different angle. So the tank at least fulfilled two different functions. Structurally this was corroborated by examination of the outfall which showed two periods of use. In the first a stone platform ca. 8,2 m wide supported the massive retaining wall. Any reconstruction must take the size of the wall into account (it still stands to a height of 2,4 m on this side) and postulate a considerable depth of water in the tank. Later, however, the stone platform was cut away by the insertion of a spillway

6 The three ledges of the triple Annell aqueduct above Gornoethle Farm.

of overlapping slate slabs. Its incline is such that, even allowing for erosion, the depth of water in the tank in this period cannot have exceeded 0,7 m. The tank's function, therefore, became simply the maintenance of a small head of water for the washing tables below.

The emphasis on changing role is important because tank C may well not be an original feature of the aqueduct: a section 12 m further south revealed the presence of two aqueduct channels, one emanating from the tank and the other evidently a bypass channel at a slightly higher level. The continuation of the aqueduct (shown in section in fig. 5) carried water to tank E (fig. 7), where the scale of engineering was even more massive. The tank (ca. 42 x 10 m in plan) was partly cut into the hillside and bordered by a retaining wall that proved on excavation to be 16,8 m wide (fig. 4). The way in which it had been constructed was clear. An inner core had been created by a turf wall (2,7 m wide) reminiscent of a military rampart. To the inside lay a clay lining, while the wall itself was reinforced on the outside by a mixed dump of shale boulder clay and rubble capped by a stone revetment. Distortion of the turf core through water pressure and subsequent soil creep makes it difficult to reconstruct the height of the outer wall, but on a minimum estimate there would be a depth of about 1,55 m inside the tank. This gives it a minimum capacity of 250 000 gallons to compare with the daily input of the aqueduct which has been estimated at a minimum of $2^1/_2$ million gallons.

The outflow from tank E was controlled by a timber sluice-gate, the details of which were excavated in 1969. As already described, the effluent dropped steeply away from this point along first a rock-cut channel, which was clear at two points and then over a stepped cascade, the ledges of wich migth have been used for gold-washing. Downstream reservoir F, served at times by a supplementary aqueduct (fig. 5), was constructed on a relatively modest scale thanks to a natural fold in the ground. It was nonetheless of structural interest; the marl core of the retaining dam showed evidence of a turf revetment to the rear and slots for an internal face of timber uprights (fig. 5). One function of the dam was to provide, via two aqueducts, a head of water for the opencast workings in the Area VII. It may, however, have served other purposes e. g. as a settling pool forming the final stage of the washing processes implied by the cascade below tank E.

Mining Technology

The importance of the role played by the tanks has, we hope, emerged from the description above. On a mining site that simply by virtue of its character must have undergone constant change, there is a danger of interpreting the function of the aqueduct and its tanks in an unnecessarily limited manner. Because the known workings at Dolaucothi constitute a vein, i. e. hard rock, mine, recent discussions have denied the possibility of using 'hydraulic methods' of mining at the site. We believe this ignores the versatility of water power in the hands of skilled engineers, a versitility that was exploited on similarly unpromising soils during 19th century lead-mining in the Pennines.

The term 'hydraulic methods' covers two distinct processes, hydraulicing soft auriferous deposits and hushing topsoil and rock debris. Hydraulicing, involving the use of a continuous flow of water in order to separate heavy minerals from alluvial or placer deposits, still ranks as one of the most important extractive techniques of modern mining. Hushing on the other hand encompasses two related functions both of which involve releasing a head of water from a dam above the deposit either in prospection or opencast development. The first was used extensively during the expansion of mining activity following the Industrial Revolution. The second, a scaled-up version of the first, involved a clearance of rubble produced by conventional opencast mining, was used extensively in the Roman period on the evidence of both Pliny and the remains at Dolaucothi but became extinct with the development of opencast mining by explosives in the Middle Ages.

Hydraulicing was used on a large scale in the Roman period at the enormous mining sites of Las Medulas and La Leitosa in the Asturias. It has been argued that hard rock at Dolaucothi rules out any possibility of this method being used. True, if one thinks only of the opencast area and the hillside above. But it could have been employed to exploit the placer deposits below the opencast in Area II on the terrace overlooking the Cothi. Similarly the use of hushing cannot be dismissed out of hand. Initially a method of prospecting, it involved diverting water into a small dam that was broken open when full; the wave of water thus released swept away the overburden to reveal the solid bedrock and auriferous veins, if all went well. As a method of prospecting hushing was an essential in mines where, as at Dolaucothi, there was a considerable overburden of glacial

7 The ledge of the main reservoir, tank E, at the south-western end of the Allt Cwmhenog ridge.

clay and mining success depended on the location of the quartz veins in the bedrock. The Elder Pliny specifically testifies to the use of this method in Spain and W. Forster's Strata (p. 164 f.) shows the method applied in the Pennines in the last century. There was a logical sequel. Once the goldbearing vein had been located, the dam would have been strengthened for conversion into a reservoir. The water could then have been used for fire-setting to aid the more conventional methods of opencast mining and to sweep away broken bedrock material of no value, so leaving a clean rock surface for the next attack on the gold bearing veins. Perhaps the confusion surrounding the possible use of 'hydraulic methods' stems from failure to realise the multiplicity of uses to which water can be put even on a hard rock site.

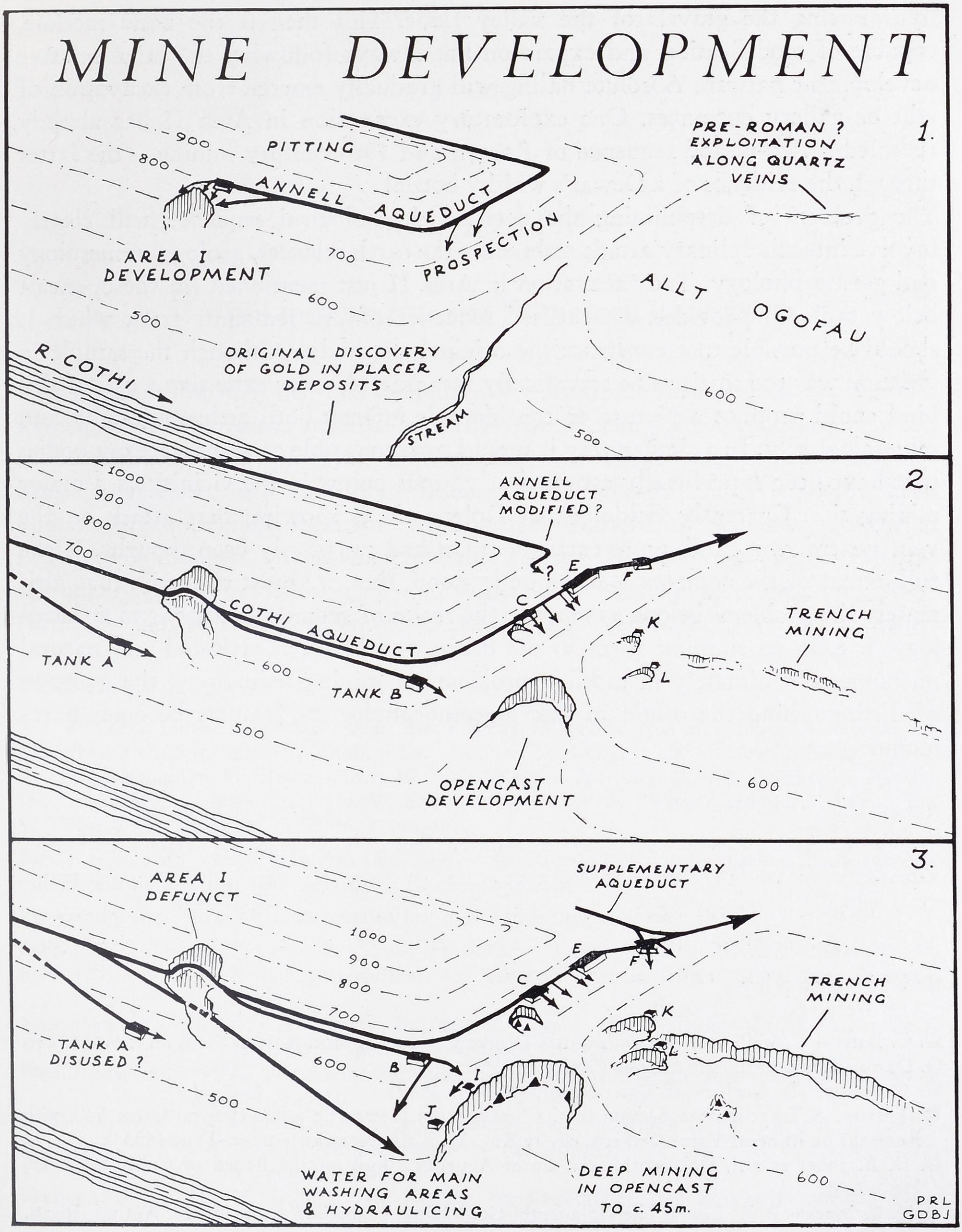
The theory explains the massive construction of the tanks and their critical position on the edge of opencasts. The largest but relatively shallow tank (E) was, from the evidence of its position (fig. 7), probably not used in this way but simply provided a head for washing purposes and/or power for a mill sited along the rock-cut outfall channel. At all accounts construction of a long, expensive and carefully engineered aqueduct argues for large scale mining techniques, the application of which was in some cases only re-discovered in the last century. So from the evidence currently available we can say that the aqueduct may, and probably did, serve several well-defined functions: washing milled ore and probably driving simple milling machinery, hushing and overburden and removing rock debris and even perhaps hydraulicing placer deposits on the terrace above the Cothi.

Synthesis (fig. 9)

We are now in a position to outline the sequence along which the mine probably developed. Potential evidence of pre-Roman exploitation in Area VIII owes its survival to the fact that the fields in question were not subject to working in the Roman period. Whatever the overall pattern of pre-Roman mining, it was

8 The excavated remains of the hut at the head of the Annell aqueduct. The stone sill-wall was capped by turf and timber upperwork.

probably small in scale. The key to large-scale Roman exploitation lay not so much in the discovery of fresh sources as in the infusion of capital to make opencast mining possible on the massive scale suggested by the visible remains. The most obvious reflection of this investment was the provision of two aqueduct systems the relative chronology of which, taken in combination with the hydrological role conversion described above, enables mining development to be reconstructed. Each opencast is dated by its associated tank or tanks and each tank, of course, relates to one of the aqueduct systems. Applying stratigraphy writ large as it were, then the Annell aqueduct emerges as earlier than the Cothi system. The principal reason is that the Cothi aqueduct bends round in a semicircle to follow the curve of the Area I opencast that was worked in the first instance by the terminal reservoir of the Annell aqueduct. The building of the later cannot have followed after a long interval, however, because a washing tank (A) was provided for the treatment of ore from the later stages of the opencast working. The basic sequence is perfectly logical and we can safely assume that initially the Annell aqueduct fulfilled various prospection roles in the col area that were taken over by the Cothi system. In the early exploration the former was a better investment of time and manpower. It was far shorter, ran at a higher level (thereby allowing a greater prospection area) and required none of the elaborate levelling nesessary for the seven mile Cothi aqueduct. Ultimately the provision of supplementary channels (p. 293) was insufficient to supply the head of water required and it was replaced.



9 Schematic development sequence of the Dolaucothi mine.

Subsequent mining development follows the growth and decay patterns of an opencast. The reconstruction (fig. 9) attempts to show this form prospection to the time when the ultimate inefficiency of deep opencast mining led to underground tunnelling. As the complex expanded control of the water supply became critical as increasingly large amounts were required for washing and perhaps hydraulicing the gravels of the valley floor. This then is the basic module, capable of modification and expansion but always following the same relative development pattern. Absolute dating will gradually emerge from excavation of adit or gallery entrances. One exploratory excavation in Area II has already revealed a two-period sequence of Roman and 19th century mining – the latter through the evidence of a Dewar's whisky bottle!

The problem of determining the detailed chronological sequence will clearly involve interdisciplinary attack embracing the earth sciences, geology, minerology and geomorphology. The excavation in Area II just mentioned (in the opencast below tank C) provided a stratified sequence of ore remnants from which it should be possible to reconstruct the original ore body. Although the sample in question was too small to be statistically meaningful, more extensive work of this kind could produce a picture of considerable interest both archaeologically and mineralogically. In a similar way it should prove possible to demarcate ore bodies that have been superficially attacked at various points in the vicinity of a major mining site. Currently fieldwork at Dolaucothi is showing that attack on the vein systems was much more extensive than had previously been thought. If the full extent of the complex is to be understood, then we must recognise that ultimately the problems belong as much to the realm of geomorphology as to archaeology, i. e. in its simplest form to the distinction between artificial and natural phenomena. Ultimately in tackling problems of mining technology, the question of distinguishing the origin of micro-geomorphological features becomes paramount.

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