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ANCIENT MINING IN THE UDAIPUR DISTRICT OF RAJASTHAN, INDIA

Report of Preliminary Investigation

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ABSTRACT

Mines at Zawar, and at Rajpura-Dariba were examined as part of a joint mining-metallurgical investigation of lead-zinc operations known to have been carried out in the area prior to the industrial period, and possibly as far back as 3,000 years ago. Substantial remains were found, and further archaeological research is recommended.

INTRODUCTION

'Ancient Mining' is a feature of all known economic deposits of copper-zinc-lead in the Rajasthan Area, and carbon 14 dating of a sample of timber found underground at Rajpura-Dariba gave an age of 3,120 ± 160 years B.P. Surface remains at Zawar and Rajpura-Dariba, including the numerous temples and scatter of pottery on smelter-waste tips suggest an important period of mining from about the 12th century to perhaps the 18th century. For Zawar this is also brought out by the scanty historical evidence which suggests a 14th century origin of zinc mining, terminating about 1812. The term 'ancient mining' therefore embraces what may be the oldest lead and zinc workings in the world, which, if the carbon dating done at Rajpura-Dariba is substantiated by other evidence, were carried out on a very considerable scale, with also a major period of working in what for convenience can be termed a late and post-medieval period. In any event, the mining and also the smelting remains extant represent a technology about which practically nothing is known in detail.

ZAWAR (see sketch map)

Modern operations at Zawar have been carried out since about 1946 by first the Metal Corporation of India, and now Hindustan Zinc Ltd., in general at a greater depth than the old miners penetrated.

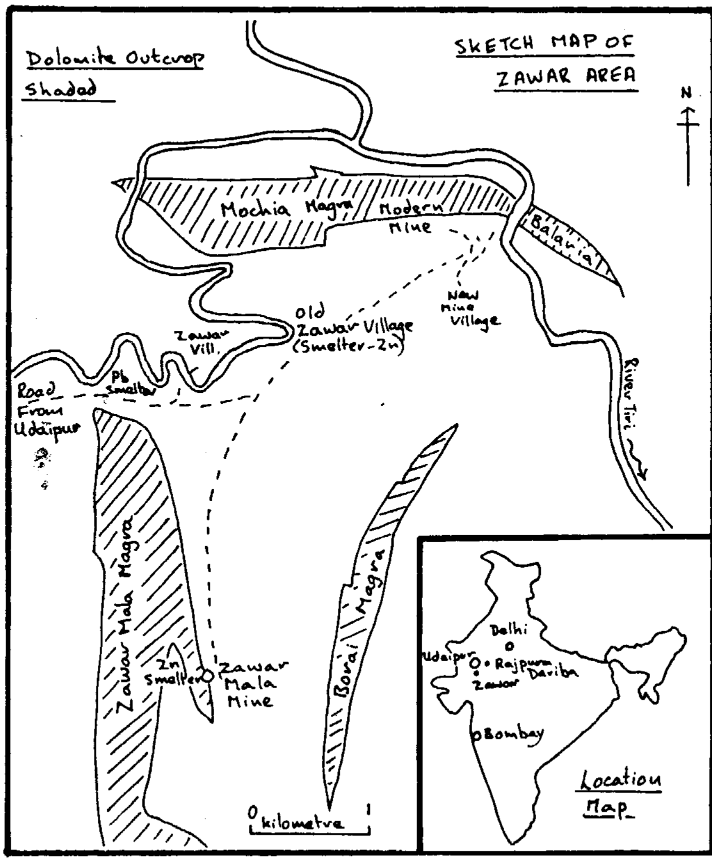
Zinc and lead sulphides (galena and sphalerite), together with pyrite and some native silver and less common minerals appear to have had a syn-sedimentary origin, and were precipitated within beds of dolomite or siliceous dolomite of Pre-Cambrian age. Subsequently the area was affected by three phases of folding and associated low grade metamorphism, which has caused remobilisation of the sulphides into shear zones, or into the noses of folds, into faults, or other tension-created cavities: howsoever, mineralisation is still confined to the dolomites, but what were fairly dispersed low values have been concentrated into 'shoots' in which > 20% metal values (whole rock) are common, and in which using hand-mining methods it must have been feasible to extract large quantities of pure mineral. Metal values are reportedly lower with increasing depth.

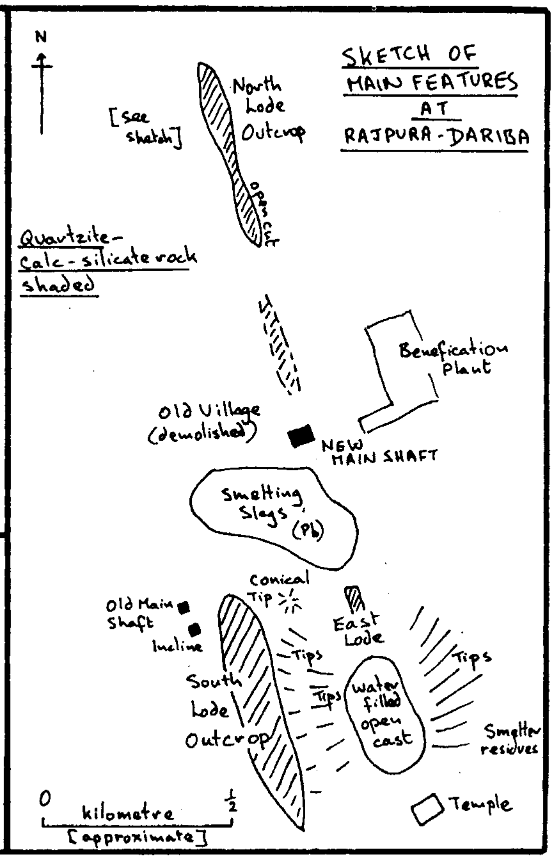
The dolomitic host rocks belong to the Middle Pre-Cambrian Aravalli system, and were deposited as subordinate members of intercalated dolomites, quartzites and conglomerates within a thick series of greywackes and mudstones, now metamorphosed into phyllites and slates, and folded into a series of isoclinal or near isoclinal folds, with the fold planes at a moderate or high angle. Zawar is a locus of intense deformation in which the normal northerly (Aravalli) trend of structures is accompanied by a west- or W.N.W.- trending series of folds. The whole is further dislocated by major longitudinal faults, and complementary shearing diagonally located with respect to the faults and caused apparently by near-horizontal displacements.

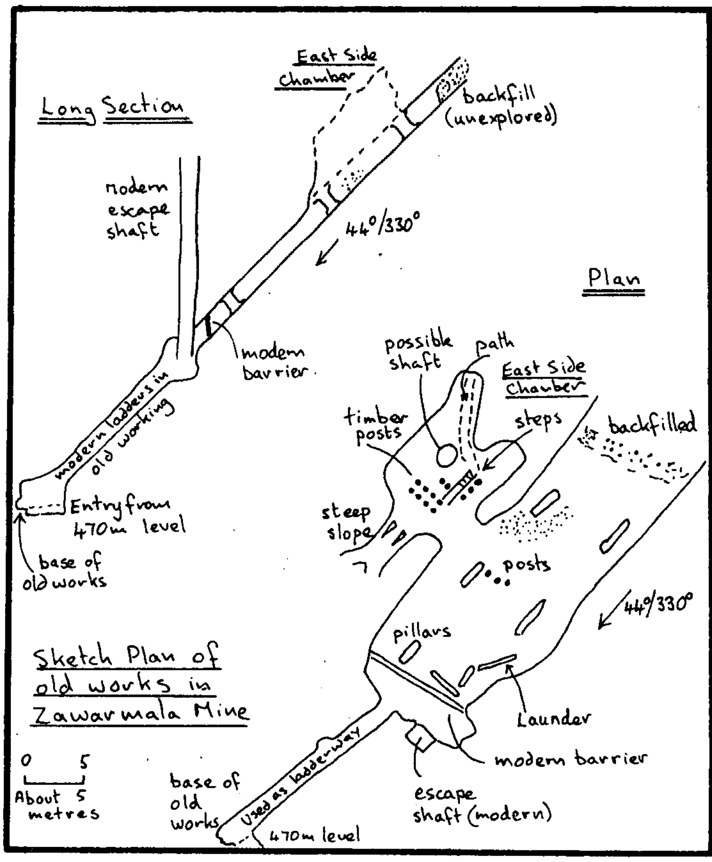
Today the more resistant dolomitic and quartzitic rocks form long ridges flanked by the phyllites, which form lower rounded hills and valleys. The valley of the River Tiri drains the whole area and cuts across the trend of the main ridges, flowing generally in an east or south-east direction. The main ridges are Mochia Magra, which strikes and extends westward to Balaria Magra, and Zawar Mala Magra, and Borai Magra which are aligned N-S and SSW-NNE respectively. All are extensively honeycombed by 'ancient workings', and all are being mined (Balaria is under development) today. So far as is known none of the old workings penetrate below valley level (about 400 m ASL), but have penetrated from the top of the ridges at 700m ASL to a depth of about 167 m at Mochia Magra, and about 200 m at Zawar Mala - in both cases probably stopped by water held up by the flanking phyllites. No attempt seems to have been made, despite the suitable topography, to enter and drain the hills by horizontal tunnelling, and this creates suspicion that ore quality had declined at depth, or that the economic structure at this stage of mining had collapsed: this may be consistent with imports of lead and copper, and perhaps zinc from the industrially developed mines of Britain in the 18th century onwards by the East India Companies. The bulk of smelting seems to have been carried out at Old Zawar Village, which is more or less centrally placed to the deposits. Two other sites were located.

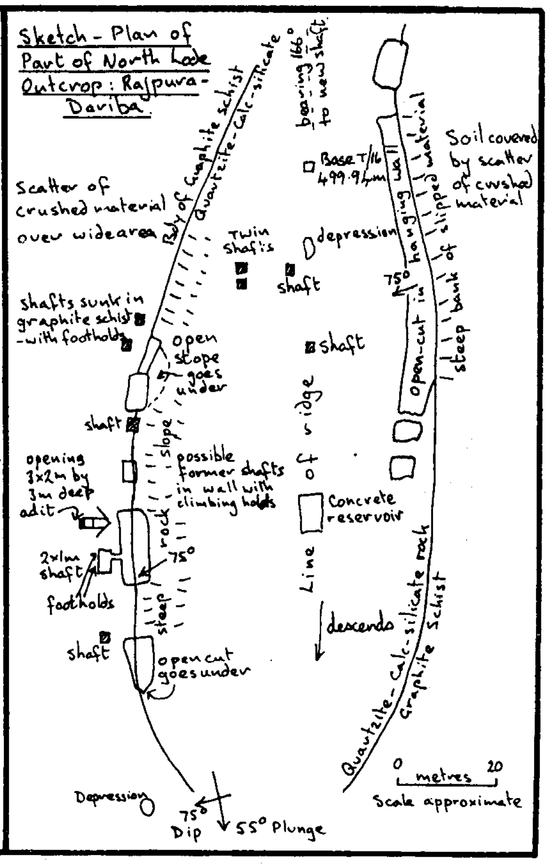
ZAWAR-MALA

At Zawar-Mala the dolomite is folded into a N-S trending tight iso-anticlinal fold, in which mineralisation is concentrated into the fold-arches and radial tension joints. At surface the fold has been denuded to form a narrow valley, which gives access to the ridge, and ancient workings along a strike length of some 3.5 kilometres. The entrance to the valley at Zawar Mala Village, within phyllites, has a low heap of retort-zinc-process debris some 60 m x 15 m x 1.5 m. Beyond this and uphill the valley bottom is strewn with mining debris, cut into by flood-water for at least 3 m. Some pseudo-gossanisation reveals outcrops of sulphide material, and both sides of the valley have numerous cave-like entrances, which give access to workings following down at angles of about 60°.


Dolomite Outcrop
Shaded
SKETCH MAP OF
ZAWAR AREA
N
Mochia Magra
Modern
Mine
Balaria
Old
Zawar Village
(Smelter-Zn)
New
Mine
Village
Zawar
Vill.
Pb
Smelter
Road
From
Udaipur
River Tiri
Zawar Mala Magra
Zn
Smelter
Zawar
Mala
Mine
Borai Magra
0 kilometre 1
Delhi
Udaipur
Rajpura
Dariba
Zawar
Bombay
Location
Map


N
SKETCH OF
MAIN FEATURES
AT
RAJPURA-DARIBA
[see
sketch]
North
Lode
Outcrop
open cut
Quartzite-
Calc-silicate rock
shaded
Benefication
Plant
Old Village
(demolished)
NEW
MAIN SHAFT
Smelting
Slags
(Pb)
Conical
Tip
Old Main
Shaft
Incline
East
Lode
Tips
South
Lode
Outcrop
Tips
Tips
Water
filled
open
cast
Smelter
residues
Temple
0 kilometre ½
[approximate]


East Side
Chamber
backfill
(unexplored)
Long Section
modern
escape
shaft
44°/330°
modern
barrier
modern ladders in
old working
Entry from
470m level
base of
old works
Plan
possible
shaft
path
East Side
Chamber
timber
posts
steps
backfilled
steep
slope
posts
44°/330°
pillars
Launder
Sketch Plan of
old works in
Zawarmala Mine
modern barrier
0 5
About 5
metres
base of
old
works
Used as ladder-way
470m level
escape
shaft (modern)


Sketch - Plan of
Part of North Lode
Outcrop: Rajpura-
Dariba
Body of Graphite schist
Quartzite-Calc-silicate
bearing 166° to new shaft
Base T/16
499.94m
Soil covered
by scatter
of crushed
material
Scatter of
crushed material
over widearea
Twin
Shafts
shaft
depression
hanging wall
bank of slipped material
steep
75°
shafts sunk in
graphite schist
with footholds
open
stope
goes
under
shaft
open-cut is
shaft
Line of ridge
slope
possible
former shafts
in wall with
climbing holds
opening
3x2m by
3m deep
adit
rock
Concrete
reservoir
75°
2x1m
shaft
footholds
steep
descends
shaft
open cut
goes under
Quartzite-Calc-silicate rock
Graphite Schist
Depression
75°
Dip
55° Plunge
0 metres 20
Scale approximate

One such mine was briefly examined - known locally as Pratapakhan. One small shaft - circular and about a metre diameter ginged with stone - is known to penetrate its workings, and several others in the area may have done so - at a depth of over 30 m. The working was entered however by a large opening on the hillside above, and followed down in a series of chambers for perhaps 80-100 m. These are highly irregular in form, but generally stratiform, except for a near vertical fault-like fissure at the lower end, which appear to have been stoped in the normal way. The shaft seen at surface penetrated the roof of the lowest chamber reached, entering some 5 or 6 metres above the floor, and would considerably have assisted ventilation as well as providing a means of access suitable for winding. There was clear evidence of the use of sharp-pointed round metal tools, with varying diameters up to about 2.5 cm, which has left circular or sub-circular marks up to about 12 cm long. Nevertheless, toolmarking was not frequent, and possibly some other means of extraction such as firesetting was used: this may account for a curious rounded dome-like opening a couple of metres wide seen in the roof. Most excavated material in the mine must have been brought to surface to account for the space in the mine, but stacked debris included all sizes of material up to 50 cm across. Much of the rock in the mine appeared to be a yellowish sandy dolomite, with a weathered appearance, some with a honeycomb structure of joints up to 10 cm apart infilled with a greyish mineral, possibly smithsonite (calamine) and limonite. At surface any tips which once must have been formed at shafts and entrances had been completely dispersed, presumably by summer rainfall, and presumably into the bottom of the valley. Age of working was not determinable.

Access to workings in the same vicinity was also gained via the 470 m level in the Zawar Mala Mine. Part of the ancient workings here have been cleared out to give access to an escape-way, and a considerable amount of old-work is easily examined. The lowest point seen is at 470 m (above sea level) or thereabouts (see sketch plan), and is the base of an inclined 'shaft' some 2 x 2 m in cross-section, and following the deposit down at an angle of about $44^{o}/330^{o}$ (TN). The roof was rounded, and at the bottom left, a rounded cavity had been hollowed out, using some form of pointed tool: walls and roof had a blackish thin sooty deposit, and in the bottom of the hollow was ashy-charcoal material, suggesting fire-setting. A similar hollow cut in the side of the shaft some 15 metres higher also had ash-charcoal in the floor, and investigation with a trowel revealed this to be a normal feature throughout the mine. Tooling could be picked out only with difficulty, but investigation with a pointed geological hammer revealed that the sheared dolomite could be removed from pillars leaving few marks. At about 500 m the shaft broadened out into wider workings, of irregular height but typically over 2 m. From here the escape route followed a modern shaft or raise, but much debris had also been removed uphill to allow a path to be made during modern exploration. The bottom section of the mine, to an unknown height, had been flooded on re-opening, and an inflow of perhaps a litre every two minutes was noted (say 720 litres/day) from this single source some six months after the last rain in what was a 'poor' wet monsoon: i.e. about half the expected 600 mm). Several 'launders' about 20 cm wide and 3 m long formed from tree trunks remained in the mine above the 500 m level, and a sample (Zawar/LW/1982/1) was taken for carbon 14 dating.

Above the 500 m level, the workings are considerably wider (some 10 m or so) with pillars left to support the roof. Waste material appears to have been stacked, presumably uphill of the then current working face, behind packs of stone, whilst wooden 'props', of about 10 cm diameter extending from roof to floor may have been placed to stabilise material on the steep slope. The remains of a pot water vessel were found in this section, of about 5 l. capacity (now in the custody of Professor Hegde of Baroda University).

At about 530 m, the workings are developed out of the main stope eastwardly into a large chamber, up to 6 m or more high. The centre of the chamber has a partially walled hollow, possibly an infilled shaft, and there are remains of a timber structure, mainly vertical posts of 7-10 cm diameter. These include a probable platform above workings extending down dip, and adjacent, timbers from floor to (originally) the roof either side of a trench, open at front (as seen by observer entering chamber) with remains of timber steps at rear. A walkway formed of stone debris extends from the back of the trench behind the 'shaft'. The timber appears to be part of a haulage apparatus, though, as suggested by the alignment, whether a windlass or even a man-powered wheel was used requires further investigation. A sample of the timber was again removed for carbon 14 dating (Zawar/LW/1982/2) and a further fragment of water vessel was also removed. The floor, slope below the haulage apparatus, shaft hollow and most of the chamber are covered in a thick layer of what was first taken to be silt, but on examination contains ash and charcoal-fragments, and small slaty fragments: presumably debris from fire-setting. So far as was seen it is the only area in the mine not either backfilled, or disturbed by modern activity, and may represent a late, even last stage of working.

The area is recommended for detailed survey and partial excavation, together with a survey of the workings as a whole, with the object of establishing methods of working, ventilation, and drainage systems. Unexplored areas (to the mine geologists also) remain updip, mainly backfilled, and offer further potential.

ZAWAR MOCHIA MAGRA

Examination of the Mochia Mine was limited by time available. Mochia Magra Hill has reportedly the most extensive ancient workings in the area, with a substantial opencast up to 40 m wide at surface, and a large number of shafts and other entrances, which have been reported to a depth of 167 m below the highest point at surface: the strike length of the largest single shoot is at least 1160 m.

A few such ancient workings, clearly exploratory and small in size were observed in both the (modern) number 3 and number 6 adits (first and second levels) in the Mochia Mine at what must have been practically the deepest points formerly reached. None of them was reasonably accessible due to either position, or unstable backfilling. Others previously visible have been closed off to facilitate modern mining, and removal of existing pillars will completely seal off exploration from the modern mine. The mine geologists consider exploration of workings from surface entrances or shafts is feasible using electron-ladder or other modern descent-ascent techniques.

RAJPURA DARIBA MINES

Rajpura Dariba is situated about 86 km NE of Udaipur, with two major modern mines - the older on the Main or South Lode developed a decade ago, with a major development on the East Lode about to go into production following intensive exploration and development.

The deposits are again considered syn-sedimentary with some subsequent remobilisation: Rajpura-Dariba has a strike length of 17 km and is part of an 80 km long mineralised belt, located in Pre-Aravalli (Pre-Cambrian) schists, which underly a wide plain, and in quartzite and calc-silicate rock which forms rugged masses which frequently stand up above the general peneplain and indicate the principal lodes. Mineralisation is found in both groups: the schists, mainly a black or graphite schist contains mainly pyrite with some sphalerite - the presence of graphite today prevents separation by flotation, and lower grade and dispersal probably prevented wide exploitation by the 'ancients' too. The principal mineralisation is contained in the quartzite and calc-silicate rocks. Quartzite has the major zinc (sphalerite) mineralisation, with some pyrite and galena, and the calc-silicate group - dolomitic marble and calc-silicate proper - contains mainly chalco-pyrite, galena, and occasionally some sphalerite. Borehole information suggests chalcopyrite at 1% average and rarely above 2% grade was not mined, but ancient mining is commonly found in the zinc-lead bearing zones. Most smelting residues found appear, however, to be for lead, but not all sites were examined. There are three outcrops of calc-silicate rock on the title, each with considerable ancient workings. The Main Lode has prominent north and south outcrops, at the second of which is the older of the two mines which works the South Lode. Parallel to the South Lode is East Lode, which has only a small and inconspicuous outcrop, but has a major opencast section which has become water-filled. The new mine will develop East Lode at depth. Ground in between the three lodes is more or less barren.

North Lode Outcrop

The quartzite-calc-silicate rock rises sharply for about 10 m or 15 m above the plateau and has a 40 m or so wide outcrop, several hundred metres long, dipping at about 75^{o} eastwardly, and plunging north at above 55^{o}. The northern end of the outcrop (see sketch map) has much evidence of ancient working, the older of which appears to be from small shafts, square in section with rounded corners and about 0.8 m across. Depth varies from 4 metres to over 10 m. Generally these follow the main dip, and were used both for climbing, using alternating footholds cut in the rock, and presumably too for removal of rock and ore. Most are cut into the hard, but somewhat shattered quartzite-calc-silicate rock, with only a short distance between each: in one instance two such shafts were cut directly next to each other, and others similar may have been cut out by later work. Some were sunk in the graphite-schist, which appears softer and somewhat weathered at the contact, probably cutting the harder rock at a depth of 10 m or so, down dip.

This earliest work has been cut through, on the east side, by several larger shafts, and what appears to be a substantial stope, open to the day. On the west side (ancient), opencast working has cut widely and deeply into the hanging wall. Further substantial open-cast work is found about a hundred metres to the south, again cutting out old shafts and related cavities.

The flat ground both east and west of the outcrop has a thick scatter of crushed rock, and what may be a small crushing stone or mortar - a quartzite slab with a bruised shallow hollow - was located.

The vein continues beyond the conspicuous outcrop southwards as an open groove, within the curtilage of the modern mine, but was not examined.

Detailed exploration and survey of this dense and apparently shallow series of outcrop working is desirable. A practical problem requiring consideration is the presence of a very high number of bats in both shafts and stopes, so that protection from Weil's disease is desirable.

South Lode Outcrop

This is a spectacular gossanised quartzite-calc-silicate mass, which has a zone of oxidation down to some 150 m, which rises to a height of 83 metres above the plain, and has been given protected status as a national geological monument. It reportedly has workings of a similar type to those noted at North Lode, but was not examined in detail. On the east side it does have substantial waste tips, which abutt and intercalate with those from East Lode.

East Lode

The only visible outcrop of East Lode is an opencast about 5 m wide, and 10 m deep for a length of about 20 m at the north end of the Lode, taken out of quartzite-calc-silicate rock. Full width of the hard rocks is not visible, but here it can be seen to be brecciated by a strike fault, which apparently is used as a marker to higher grade mineralisation. At the south end, about half a kilometre distance, the end of the Lode is marked by a Temple, rising above a large water-filled hollow, clearly the result of opencasting since vast waste hillocks rise to 20 or 30 metres high on either side, though not along the lode from the end of the 'lake' to the vein outcrop noted. On the west side these meet with the tips from the South Lode, but at the northern end a conical tip, some 40 m high above the plain, and some 10 cm high on its west wide of the rising ground, may indicate a shaft, which might be expected to meet South Lode at depth (dip 70° eastwardly). Beyond the small visible outcrop are vast slagheaps, apparently lead, since a sample was found, and they are without retort waste, covering an area of some 500 m x 200 m, with an average depth of approaching 5 m. Further waste-heaps from smelting occur to the SE of the site but were not examined.

Unfortunately underground examination was not possible due to maintenance work on the shaft, but it is on timber from this East Lode that unexpectedly old carbon 14 dates have been determined, resulting from the modern exploration and development of the new mine.

Carbon 14 results (Reference date 1950)

Location		
South Drive	400 m level (90 m depth)	3120 ± 160 B.P.
East Lode	263 m depth borehole	1840 ± 130 B.P.
East Lode	4-5 m depth	2200 ± 100 B.P.

(National Physical Laboratory Ahmedabad, and Teledyne Isotopes, U.S.A.)

The circumstances of mining on the plain add further lustre to these 'ancient' achievements: water table is but 10 m or so below the plain, which is at about 490 m altitude. Possibly lateral migration of water was not a major problem, but with a rainfall of some 600 mm per year, over an area of opencast and adjacent inward facing stopes of about 4 hectares, and possibly as much again, the removal of some 100,000 to 200,000 tons of water annually would be necessary. Whilst this can, with difficulty, be conceived in a pre-industrial age for the open-cast, it cannot for the deep workings, which obviously must form an earlier phase of mining.

A small collection of artefacts from the mine has been preserved by the Company: These include the remains of a basket, presumably used for carrying ore, and a small saucer-like oil lamp, as well as a timber stemple - this last excellently preserved due to immersion. More timber is apparently currently accessible in the mine, but the section of greatest depth discovered by borehole will not be accessible for some years. Monitoring of old works underground is obviously desirable during mining operations as they become accessible.

DISCUSSION

In the industrialised countries, mines such as those examined would have been worked, and reworked for low grade ore using modern methods. In India this Industrial Period phase seems almost entirely to have been omitted. As a result the mines have been left so as to leave exposed techniques which have not necessarily changed for some 2,000 years and more, i.e. since the introduction of metal tools. In terms of scale the mines at Zawar, notably the Mochia Mine, and both the opencast and deep workings at East Lode at Rajpura-Dariba are the equivalent of any pre-industrial mines to be found in Europe, and possibly of a (much?) earlier period, whilst the centralisation and scale of metallurgical remains suggests also a high degree of organisation.

A great many problems remain to be elucidated about the technology for both mining and metallurgy, which are intimately inter-related. Of these the time-scale is of outstanding interest. To what extent is the series of early dates for Rajpura-Dariba typical? Is this simply a case of following a narrow shoot (or shoots) of rich ore downwards, leaving lower grades for more massive medieval or post-medieval exploitation? Or had truly 'ancient' technology been developed, with corresponding organisational and management skills to deal with large quantities of water as well as ore? The known survival of timber, and of dateable ceramic artefacts offer the possibility of establishing criteria by which 'ancient' mining technologies in general may be compared in both India and elsewhere.

Though various possibilities easily present themselves, little in fact is understood in detail about ancient, or indeed simply old or pre-industrial mining technology. How was water removed from the workings at a depth of 100 or 200 metres or more? Firesetting seems the principal means by which hard rock was broken - but in deep, narrow oreshoots, and in such large mines, this would have posed very considerable problems in ventilation. In many instances - with wet rock, or in shaft sinking, then firesetting is inappropriate. What techniques were used for this purpose? Was ore and waste simply carried from the mine, or were methods of haulage and winding developed using either man or bullock power? Suitable methods on a smaller and simpler scale can still be seen in the area for irrigation purposes from wells.

Finally, mining and smelting were a major part of the entire economy of the areas: co-ordinated examination of mines, metallurgical sites, and habitation sites of the areas should enable a reconstruction of that economy through time.

Currently the sites are generally not immediately threatened, and indeed mining facilitates access. Some will be lost however by progressive removal of pillars in the forthcoming decade, and others will be blocked off to improve safety and ventilation. Some, expecially at Rajpura-Dariba will only be open during mining, due to flooding, and others are vulnerable to open-cast techniques. Mining is inevitably at times a destructive activity, and experience suggests recording preceding or concurrent with mining is the only feasible long-term way of preserving data. From discussions it appears that HZL are willing to provide facilities to allow such work to be done, if other financial support is forthcoming.

RECOMMENDATIONS

1. A detailed examination, involving survey and limited excavation, be made of the underground workings in Zawar Mala Mine. Suggested time - about two weeks, for two people with local assistance.

2. Further examination and survey of suitably accessible workings near surface at Zawar Mala, as a comparative study to establish similarities or differences in technical methods of mining. Suggested time - about two weeks.

3. Preliminary examination of both shallow and deep works on Zawar Mochia Magra Hill to determine suitability for limited but detailed survey. This could probably be carried out in conjunction with the above two surveys.

4. Survey of selected works at Mochia Magra: two weeks.

Together with a preliminary examination of copper mines (in association with Professor Hegde) and possibly an underground visit to Rajpura-Dariba, this would complete a first phase investigation of the mines on a time scale envisaged as comparable with a joint excavation of smelting facilities and Old Zawar Village by Dr. Craddock and Professor Hegde of Baroda University.

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December 1982.