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ADICHANALLUR: A PREHISTORIC MINING SITE

B SASISEKARAN*, S SUNDARARAJAN*, D VENKATA RAO*, B RAGHUNATHA RAO+, S BADRINARAYANAN++, S RAJAVEL+++

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The geo-archaeological survey at Adichanallur and Krishnapuram was carried out in the year 2004. The resultant study revealed that the so-called prehistoric burial site were one of the longest open cast mines of ancient times. The mined materials contained copper, gold and iron at Adichanallur and iron at Krishnapuram. The collected samples of ore, slag and some of the copper and iron artefacts from the exposed burials were analysed for their elemental composition. The study of metallic artefacts revealed that the technology of melting, casting and metalworking was prevalent in that period at Adichanallur. The age of the burials were ascertained through the dating of the pottery pieces from different level by Thermo Luminescence (TL) and Optically Stimulated Luminescence (OSL).

Key words: Adichanallur, Chemical composition, Copper artefacts, Iron artefacts, Mining, Optically stimulated luminescence, Thermo luminescence

INTRODUCTION

Adichanallur, the pre-historic mining site [8°38′28.5″ N Lat. and 77°51′51″ E Long.] is located 24 km south-east of Tirunelveli and about 9 km north of Korkai in Tuthukudi District of TamilNadu. At the request of T. Satyamurthi, then Superintendent Archaeologist, Chennai Circle, Archaeological Survey of India, the scientists from the National Institute of Ocean Technology (hereafter NIOT), Chennai, carried out geo-archaeological survey at Adichanallur. While carrying

* National Institute of Ocean Technology, Chennai
+ Department of Mechanical Engg. HCE, Padur
++ National Institute of Ocean Technology, Marine Archaeology Branch, Chennai
+++ Archaeological Survey of India, Epigraphy Branch, Chennai

out the geo-archaeological investigations in that area, the scientists chanced to find similar ancient open cast mining site at Krishnapuram. The ancient mining site at Krishnapuram is located 15 km from Tirunelveli towards Tiruchendur at 8°40′50.5″ N 77°48′23.20″E. The village Krishnapuram was mentioned by Alexander Rea as one of the burial sites along the banks of the river Tamraparani. The Tirunelveli-Tiruchendur highway bisects the ancient mining site at Krishnapuram. The area surveyed by NIOT falls on the SW side of the village and vestiges of burial have not been encountered in that area. However, the burials reported by Rea are probably nearer to the banks of the Tamraparani River.

Background Study

The site Adichanallur is closer to Srivaikundam town situated on the southern bank of the River Tamraparani. The credit for the discovery of this burial site, as early as in the year 1876, goes to Andrew Jagor of Germany. At that point of time**,** he unearthed number of bones, iron artefacts, burial urns, and copper objects. The Adichanallur burial site received further attention in the year 1899 when Alexander Rea of Archaeological Survey of India (hereafter ASI) undertook excavation for five seasons from 1899 onwards, followed by Louis Lapicque in the year 1903-04 and Dr. J.R. Henderson in the year 1915. Alexander Rea’s excavation brought to light the largest number of artefacts unearthed so far from a burial complex that includes iron swords, javelins, trident, spear, dagger, spades, lamp hangers and tripods, besides objects made of copper and gold. After a gap of hundred years, the ASI, Chennai Circle, under the direction of T.Satyamurthi, carried out excavations for two seasons (2004 and 2005).

The geo-archaeological study indicated that the famous burial site at Adichanallur and Krishnapuram were primarily industrial mining centres where the ancient metallurgists mined copper, iron and gold in the former and only iron in the later. The usage of mined pit in these centres as a burial site was an afterthought and the people utilised the 6 to 3 m deep shallow mined pit to bury their dead.

Regional Geology

The survey area carried out by NIOT at Adichanallur starts from 8°38′28.5″N lat. and 77°51′51″E long. and extends up to 8°37′38″N lat. and 77°52′28″E long. The rocks forming this complex are of Archaean age. The map published by the Geological Survey of India (2001) indicates this area to be made up of Khondalite and Charnockite rocks. The Tamraparani River mainly drains the area. The WNW-ESE trending Achankoil – Tamraparani fault forms part of the area. It is a well-known fault and extends from East to West coasts of India. The lineament map, which has been found in the publications show that there are three main lineament features aligned in the following directions: WNW-ESE, NS and NNE-SSW.

The Achankoil-Tamraparani fault marks the northern boundary of the Kanyakumari- Tamraparani belt. Ultramafic bodies near Arimanallur, and a number of Pyroxene granulite bands, in the terrain possibly represent ophiolite assemblages in the suture marked by the Achankoil lineament. The ancient suture was probably ruptured later with the emplacement of alkaline rocks like Puttetti Syenite and Chengannal alkali granite apart from other major intrusive. The presence of ophiolite indicates an original marine origin.

Site Geology

The area forming the mound is seem to be a highly sheared and fractured reef quartz (Fig. 1) which has several lensoid, limonitised and gossan bearing zones (Fig. 2) and contain small and long linear structures of host rock which is amphibolite (Fig. 3).

Fig. 1. Quartz Mound – Adichanallur

There are amphibolite outcrops both to the east and to west of the quartz and near the contact with the quartz showing the effect of metamorphism. There are minor patches of quartz chlorite, quartz sericite schist like occurrence.

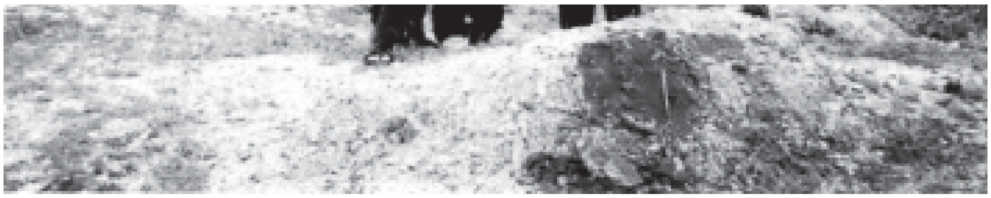


Fig. 2. Gossan bearing zone

Fig. 3. Host rock amphibolite (dart) within Quartz

Geophysical Surveys

The Geophysical survey at Adichanallur was carried out by the geophysicists from the National Institute of Ocean Technology (NIOT) to find out the potential zone for excavation. Taking into consideration the field conditions and the availability of instruments as the first case NIOT carried out Electrical Resistivity Sounding (ERS). The Vertical Electrical Soundings (VES) were carried out with model DDR2 Electrical Resistivity Meter. Schlumberger configuration was used in all these soundings. The Maximum 60 m separation for current electrodes AB was given for the effective depth penetration up to 20 m from the subsurface. Based on the survey two regions viz., the region of high resistivity 2500 - 976.0 Ohm-m and thickness varying from 4.7 to 2.7 indicating presence of quartz veins and area of low resistivity 32 to 11 Ohm –m and thickness 8 to 6.7 indicating probably dumped soil in the mined pit were identified.

The main places were the prehistoric burial site as seen is originally without the sheared and fractured quartz intrusive, which have been worked diligently by the early minors. The examination of the site clearly shows that the northern part of the area had several old workings with the deepest one where the mining has gone down to a depth of 6 m. Rea mentions that wells were dug up wherever quartz vein was found to place the urn. According to him, the wells were of various sizes varying from 1.5 m to 5 m (Alexander Rea: 1906). These four to six meter deep old workings were used as wells to intern the urns as shown in figures four and five. The previous excavators of the site believed that after removing the lensoid bodies of the ore completely, the prehistoric people have placed big urns containing the remains of human bones often along with several articles made of copper, bronze, iron, and steel and some gold (Alexander Rea:1906) as shown in Figs. 5 to7.

Fig. 4. 4 m deep old working in the northern area

Fig. 5. Urn Burial-Adichanallur

Fig. 6. Human skeleton, potteries and broken sword inside urn

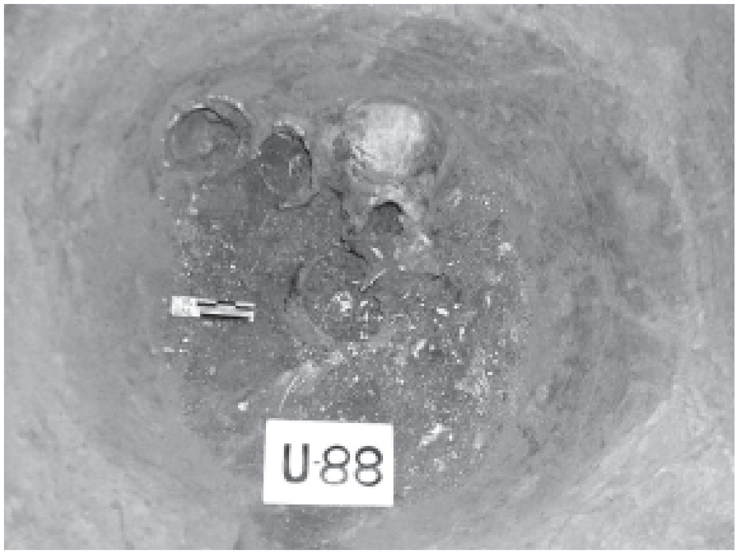
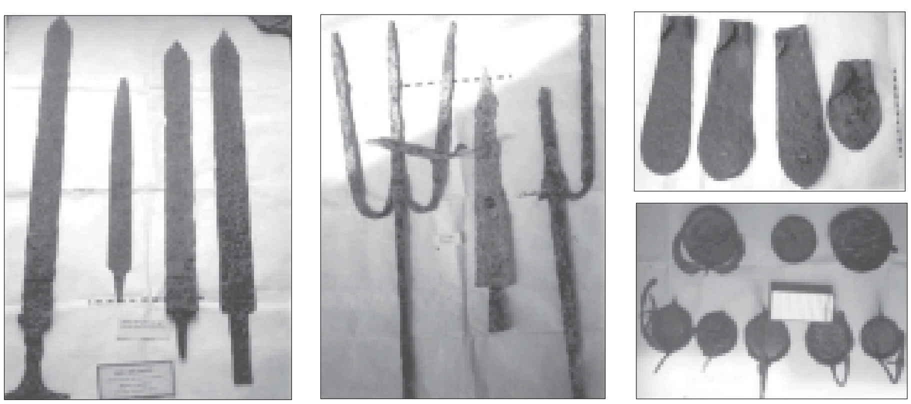


Fig. 7. Human skeleton, potteries and copper rings inside urn

The earlier excavations carried out by Rea and Jagor, brought to light, the largest number of iron and copper artefacts unearthed so far in the Iron Age sites in India and it constitutes the single largest antiquity of all the metallic finds from a site.



Figs. 8, 9, 10, 11. Iron artefacts Adichanallur

It is seen that most of the ores have been locally obtained. The examination of the northern part of the area reveals several evidences of calcinations of the ore, smelting and extraction This was revealed by the presence of charcoals or peat in the dug up area along with the ½ to 1 m burnt ash and pieces of broken hearths used by the early smelters (Fig.12).

Fig. 12. Peat and charcoal – smelting area

In this zone, the altered body and quartz vein is seen to expose minor vein and veinlets of green coloured malachite ore (Fig.13). To the south of this are the altered caught up patches of amphibolites and the quartz vein here is seen to be grey and greasy. A detailed examination brought out thin specks of pyrite and pyrhotite. It seems that this zone has been worked for their auriferous content and the extracted gold appears to have been used in making some of the ornaments

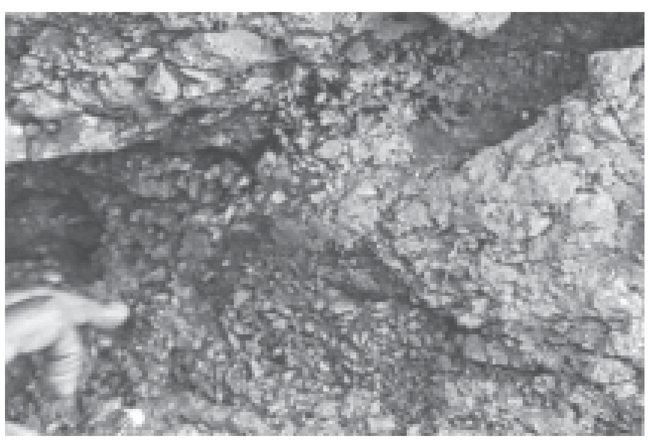


Fig. 13. Green coloured malachite veins in the crushed host rock

found in the burial urns. The probable extent of this old working is marked in the map. Further to the WSW of this old working on both sides there are quartz vein, which has been crushed and fractured with several gossan like vein fillings. At places close examination reveal the presence of the original iron ore.

This occurs on both to the East and West whereas in the middle portion where the amphibolitic zones of both hanging walls and footwalls appears to have been worked for copper. There are left out minor specks of malachite and azurite (Fig. 14).

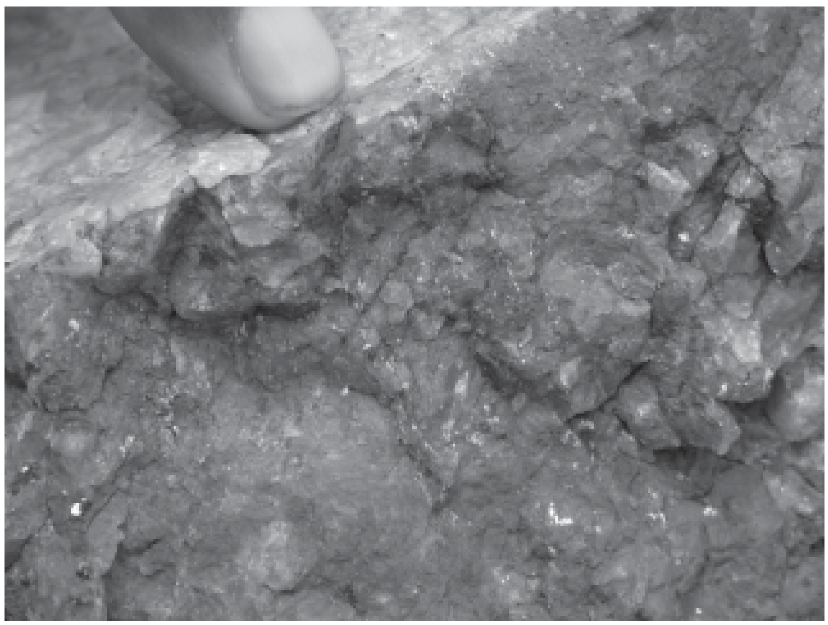
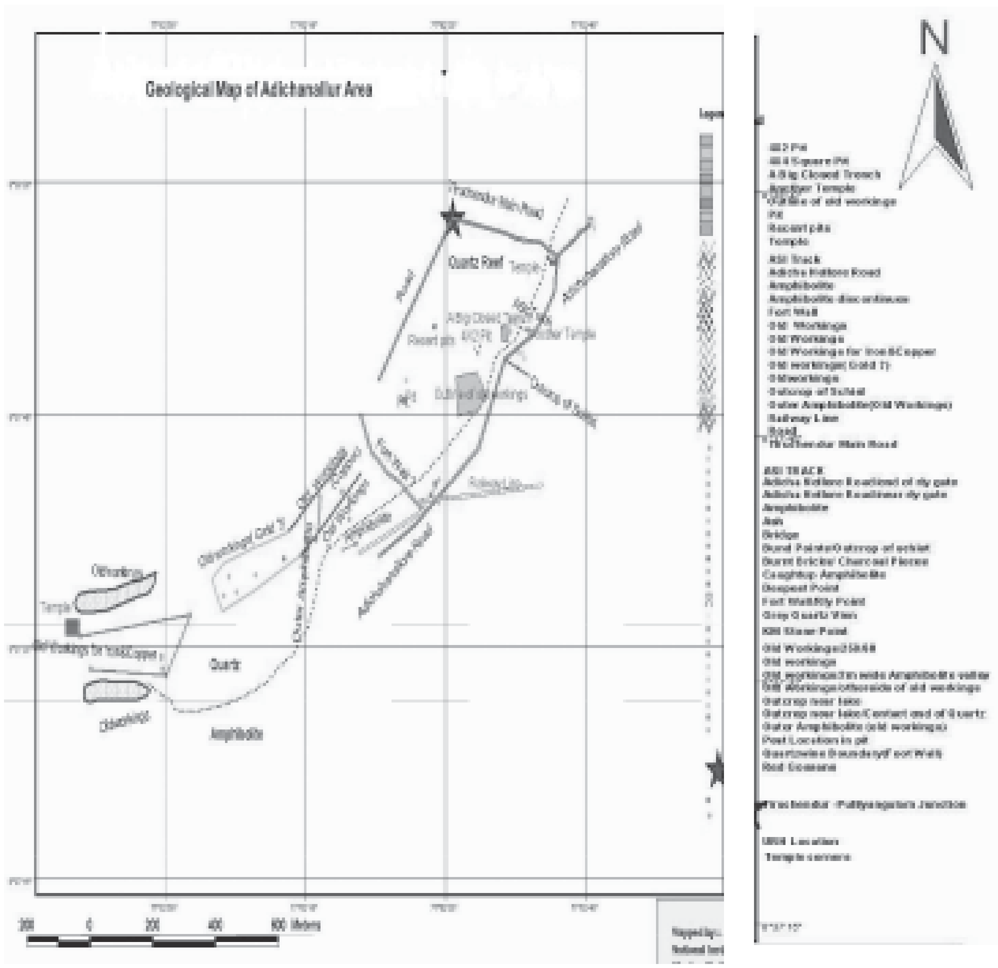


Fig. 14. Presence of left out malachite in the Quartz

This zone is seen to have an overall length of 400 m and average width of 75 m (Map-1). These are often worked to a depth of about 6m. Parallel to this both to the East and West there are some old workings having similar set up.

The ancient miners followed the Quartz vein and collected the ore until their primitive technology permitted them in their exploitation of the minerals in that area. Ore and slag samples were collected and were analysed in the ICP-MS Lab at NIOT for the identification of the ore typology. Soil and pottery samples were sent to Luminescence Dating Lab at Manipur, to date the samples through TL/OSL methods. The scientific study and the recent excavation by the ASI in the



Map 1. Adichanallur mining area

small area at Adichanallur enabled the scientists and archaeologists to infer that the site was a thriving mining and industrial centre. The mining activity continued there for over c.2000 years from prehistoric times (c.1500 BC) and continued until early medieval period (775 AD) as suggested by ^{14}C date of a wood sample and copper alloy composition unearthed.

Adichanallur-shallow Mining Pit

The urns are seen to contain artefacts mainly made up of copper alloy, iron and gold. These metals appear not to have been transported from long

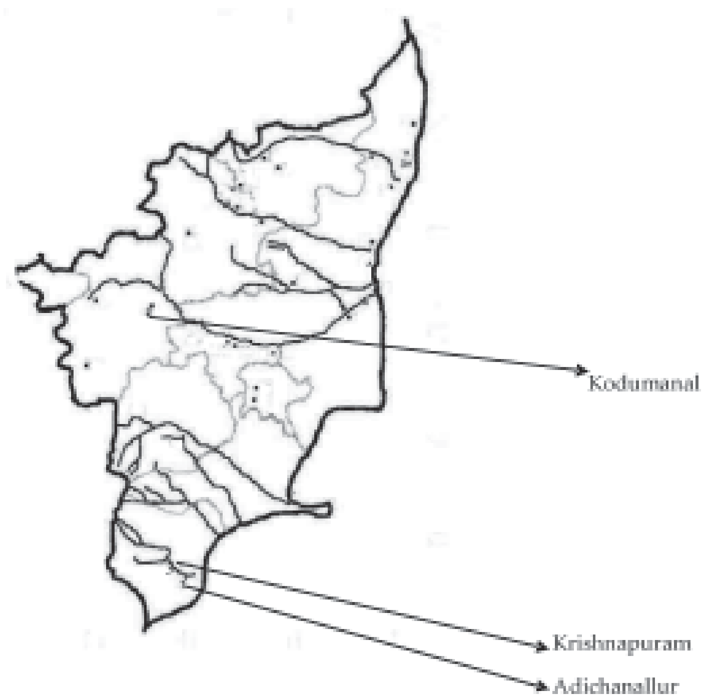
Fig. 15. Dismantled industrial site- Adichanallur

distances but are locally mined and smelted, as there are many evidences of smelting like the presence of burnt bricks, furnace, charcoal pieces, slag dumps and beneficiated ore pieces. The entire area presents a picture of hectic multifaceted activity wherein the ancient miners would appear to have perfected the technology to use them to extract the metals, since the top portions are oxides ores like copper and iron.

The miners were able to reduce them easily by mere addition of charcoal and lime as flux, in view of the fact that the iron samples indicate the presence of calcium in all the samples analysed, and successfully extracted the metals. At places, the mine dumps are seen to contain much of the dumped materials. The old working appears to proceed in approximately ENE-WES direction. One part of the old working is seen for more than 1 km long with varying widths. It is evident that the ancient miners have followed the ore body along its strike direction and have successfully mined. If it was for the burial of urns only, there is no need for them to excavate all along the ore body. However, the majority of the urns that were excavated by ASI during the year 2005 are material confined to the sheared quartz vein adjoining the main Tirunelveli, Tiruchendur road. In fact the entire quartz vein which has host rock stands out as a geomorphic high and once the quartz vein is over the regional ground level, it is seen to fall drastically forming local streams adjoining the main Tamraparani River.

The entire area (Map 1) is full of old working, potsherds, burnt bricks and amphibolites. In fact, what is presently thought to be a fort wall does not have enough elevation and the railway line on the Adichanallur road cuts this. It shows that these are only dumped material and none of the features associated with fort wall could be seen. The test geophysical survey has also picked up trenches at right angles to the fort wall and it helped us to have a picture of the site and clear our doubts.

The old working are seen to temporally terminate near the Rama temple (8°37′28.5″N, 77° 51′51.5″E) adjoining the Pulinankulam. Even this 1 km long old working have small old working parallel to it on either side and it looks as though that the central major old working is along the got up patch of amphibolites and weathered metavolcanic. Whereas the two minor one, on either side, appear to be the working on the footwall and hanging wall of quartz vein with the local amphibolites. It is seen from further SW of the area, the topographic high indicates the presence of quartz vein and it coincides with the continuation of the old working. The extent and continuation are to be studied further and mapped.



Map 2. Prehistoric Industrial centres in TamilNadu

Krishnapuram

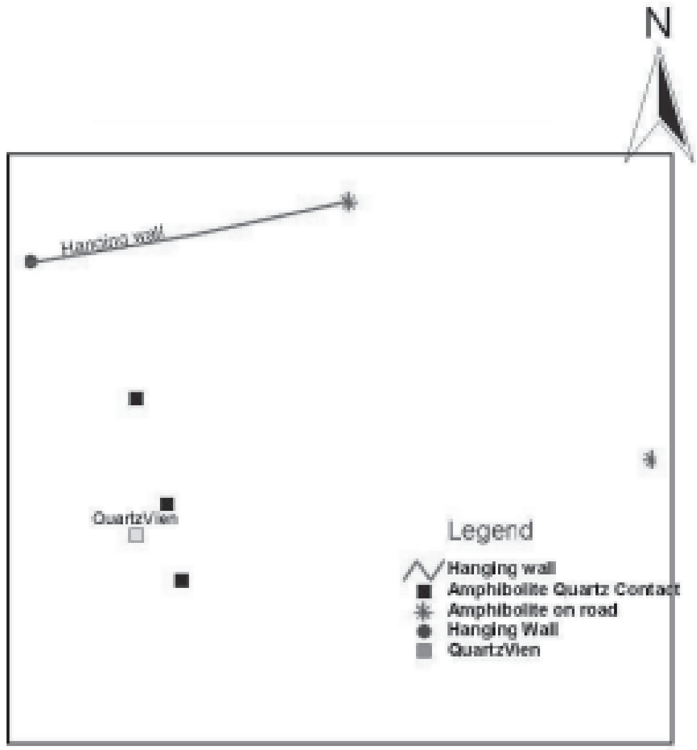
Krishnapuram, reported by Alexander Rea, for its burial mounds, is located 15 km from Tirunelveli towards Adichanallur. Krishnapuram probably derived its name from the ancient word '*kṛṣṇa ayas*' which is said to refer iron in the *Brāhamaṇas*. In addition, a similar quartz vein with amphibolites patches as at Adichanallur is located near Krishnapuram. Here, in the shear quartz vein amphibolites (Fig.16), patches of amphibolites along with soft metavolcanic are seen in a similar setting to the west of Adichanallur. These are seen near locations

Fig. 16. Sheared and Fractured Quartz - Krishnapuram

(co-ordinates, 8°40′50.5′′N, 77°48′23.20′′E, Map.3). Since the quartz body along with associated formations cut across the road and rises as a similar mound, it is obvious that the ancient miners worked on this belt for various types of ores. Old workings are seen on both sides of the road trending ENE- WSW. Future excavations at Krishnapuram could throw light on the metals extracted and its relation to Adichanallur.

Dating of Adichanallur Artefacts

The materials from Adichanallur excavations have evoked keen interest about the age of the finds, since they constitute the largest metal and burial appendages from a burial site. Tata Institute of Fundamental Research (TIFR) Lab analysed a wood sample from the excavated material in the period 1899-1905. The sample gave a ^{14}C determinant of 775±95 AD, which at that time was



Map 3. Krishnapuram-Geological Map

considered widely divergence from the archaeological estimates, as the sample is supposed to associate with Urn- burials of iron age/ early historic period viz., c.500 BC to 300 AD (Agrawal, et al. 1964). However, the results on some of the copper alloy metals by Madras Museum indicated the presence of tin in the range from 22 to 25%. The higher tin percentage of Adichanallur copper alloy reveals similarities with the bronze coins issued by the Pallava dynasty analysed by the authors, wherein the percentage of tin varied between 18 to 26%. This shows that the date 775±95 AD obtained for the Adichanallur sample was not in wide divergence as predicted earlier, but on the other hand points to the continuance of mining activity and the practice of burying the dead in urn at Adichanallur as recent as the early medieval period (c.400 to 800 AD) in that area.

Optically Stimulated Luminescence (OSL)

As already stated, the area was thought to be a burial site and generally, an age of 2000 years was assumed for the Adichanallur burial. Hence, NIOT has sent various types of pottery to Manipur University, where Dr.Raj Kishore Gartia carried out the Thermo-luminescence (TL) and Optically Stimulated Luminescence dating (OSL) of the samples. As per the usual procedure, quite a few samples of the various types of pottery were sent to him for dating. The result of his study on the age of some samples given are tabulated below.

Table 1

Sl. No.	Sample No.	Trench No.	Urn NO.	Age [BP]
1	1	2zB16	U-52	3000±700
2	4	2zC16	U-21	2700±600
3	8	2zB17	U-104	3160±600
4	13	2zC15	U-10	3400±700
5	16	2zB17	U-93	2600±500
6	Thick pottery	2zB117/2	U-	2500±530
7	Thin pottery	2zC16Q2- layer	U-29	1920±350
Sl.No	**Sample**			
1	Wood piece	^{14}C Date [TIFR,1963]		775±95 AD

The OSL date of c.1500 BC derived for Adichanallur burial containing copper artefacts shows that the mining of ore for the extraction of copper at Adichanallur started much earlier than perceived and contradict the hitherto held view that copper was imported into the south in Prehistoric times until the exploitation of mines at Agnigundala and Mailaram in Andhra region in early historic period.

Probably the older dates, as shown in Sl. No. 4 in the table 1, coincide with the entry of Iron Age period in TamilNadu, wherein the ancient people have obtained copper along with iron and gold and then smelted them to make various copper alloy objects. The mining activity continued until the early medieval period as indicated by the carbon dating (775AD) and alloy composition of bronze. In fact, this area has a maximum number of copper related artefacts anywhere found in the various archaeological sites in south India.

Chemical Composition of the Iron Ore

Three samples of the magnetite ore collected from Adichanallur area were tested in the ICP-MS Lab at NIOT. The magnetite ore in the Adichanallur mine are rich in Titanium with the specific gravity of 5.18. One of the sample analysed revealed the concentration of Titanium around nine percent and this goes well with the recent attempt by a private industry (TATA) to set up a titanium manufacturing facility in Tuthukudi district, near this site which is known for Titanium deposits. The following is the breakup of major elements in the samples analysed.

Table 2. Elements in Wt%

Major elements	Sample Ore. No. 1	Sample Ore. No.2	Sample Ore.-No.3	Sample-Slag
Fe	46.77%	46.8%	47.12%	6.045%
Ti	2.59%	0.185%	9.0%	0.59%
Mn	0.12%	0.015%	0.04%	0.07%
Zr	0.05%	0.005%	0.15%	0.005%
Sn	0.06%	0.07%	0.005%	0.08%
V	0.01%	0.07%	0.02%	0.01%
Mg	0.49%	0.205%	0.74%	
Cr			0.005%	
Ni			0.005%	

Apart from this, the oxides and carbonates of the elements constitute the remaining percentage of the study material, besides a minor amount of radioactive elements like Uranium etc. The slag material collected near the smelting area was analysed and the composition of slag indicate the presence of Fe, Ti, Mn, Zr, Sn and V with iron as dominating element.

Metallurgical Study on Adichanallur Artefacts

The iron and copper artefacts from Adichanallur find were subjected to micro structural and elemental analysis. The elemental results are given in the form of a table.

Copper Alloy Ring

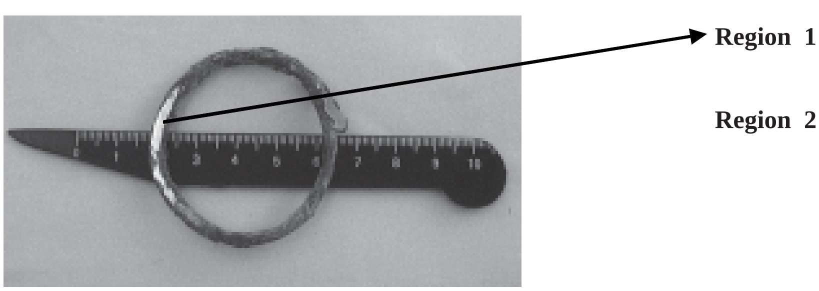


Fig. 17. Bangle-Copper-Arsenic alloy, Adichanallur

Physical Appearance

The visual examination of the ring measuring about 4 cm in diameter and 4 mm in thickness revealed heavy encrustation with patina.

Elemental Composition

Three copper alloy objects recovered from Adichanallur were analysed for elemental composition at RRL laboratory, Bhubaneswar. The artefact taken up for study was made from an alloy of copper containing 87.48% with arsenic 4.62% and Lead 2.68% as major alloying elements. Iron, tin, gold and nickel were the other alloying elements found in the percentage of 1.46, 0.95, 0.81 and 0.033 wt. percentage respectively. The use of arsenic as an alloying element was not found in the contemporary chalcolithic culture in other parts of India. However, arsenic as an alloying element was found in Harappan (Indus-Sarasvati – 3500-1600 BC) culture, that existed anterior by a few centuries to the one exposed at Adichanallur. The cranial elements present at Adichanallur show that the ancient population in that area was not a homogeneous one but a mixed of Australoid, Armenoid and Mediterranian. Chaterjee and Gupta (1963) in their study pointed out that the Adichanallur crania are more aligned with the Harappa groups than with the Vedda (Kenneth A.R. Kennedy 1986).

The presence of arsenic in higher amount in some of the copper alloy from the recent excavation (2004-06) demonstrates the probable migration of metallurgists for exploitation of minerals to the southern region from other parts of India. The presence of four to six percent arsenic in the three samples analysed indicate that it was not an intrusive element but a deliberate addition as an alloying element, since the addition of arsenic by one percent increases the hardness of copper from 124 to 177 VHN. The presence of skilled metallurgists from other

Table 3. Adichanallur- Elemental analysis of Copper samples in wt. %

Elements	Sample No. 1	Sample No. 2	Sample No. 3
Fe	0.20	1.46	5.25
Cu	91.47	87.48	87.95
Ni	0.029	0.033	0.046
Au	0.99	0.81	0.90
Sn	-	0.95	-
Pb	-	2.68	-
As	6.47	4.62	3.85

parts of India for exploitation of minerals was attested not only by the typological similarities of copper bowls, strainer and lid with flower motifs with branched out buds from Adichanallur to the copper objects excavated from Kodumanal in Tamil Nadu (c.300 BC) and Mahurjhari in Maharashtra (c.500 BC), but also in the recovery of potsherds bearing the names like nigama, visaki, kuviran, varuni and asadan of north Indian origin in Brāhmī script at Kodumanal, an iron age industrial centre in Erode district (Rajan:1994).

The authors have analysed copper alloy samples from Iron Age to early medieval period and the results are given below in table No.4. The tables 3&4

Table 4. Samples 1,2,3 in ppm, sample 4 in wt. %

Elements	Sample No. 1 Kodumanal Sieve [c.300BC]	Sample No. 2 Early historic Coin.1 [c.200BC-300AD]	Sample No. 3 Early Historic Coin.2 [c.200BC-300AD]	Sample No. 4 Pallava Coin [c. 700AD]
Fe	0.115	0.416	0.261	4.72
Cu	40.295	34.669	119.003	<74
Ni	0.021	0.013	0.240	1.60
Au	0	0	0.99	0
Sn	1.771	1.771	12.566	>18
Pb	4.117	0.021	0.229	0.004
As	0.033	0.021	0.150	>0.168
Mn	0	0.001	0	0.002
Zr	0	0	0	
Ti	0	0.001	0	0.002
V	0.001	0.001	0.001	0.001
Mg	0	0	0	
Cr	0.001	0.002	0.001	<0.036
Sr	0.011	0.002	0	
Zn	0	0.010	0.017	0.003
Al	0.006	0.020	0.003	0.235
In	0	0	0.001	
Rh	0.001	0.001	0.001	
Co	0.001	0.001		0.0324
Br	0.011	0.012		
Bi	0.011	0		
Ag	0.021	0.023		
Sb	0.029	0.004		<0.003
S				0.0836
Si				0.001

show the evolutionary stages underwent by copper alloy in Tamil Nadu. From arsenic copper it changed to low tin and lead in Iron Age. The early historic and medieval periods witnessed the increase in weight percentage of tin to 12% and 18 to 26% respectively.

As discussed earlier, some of the samples from the earlier excavations by Alexander Rea were analysed by Madras Museum (1998) and Sharada Srinivasan (1998). The study indicates that they were high tin bronzes with a tin content varying from 23-25%. The higher percentage of tin in some of the artefacts analysed from Adichanallur probably indicate their closeness in time to the early medieval period.

Metallographic Study

The copper alloy ring (arsenic bronze) was polished at two places to study the micro structural details at different regions. Microstructural studies in region-I revealed hot and cold working. The artefact was worked slightly at higher temperature resulting in the formation of parallel bands, strain marking and extensive elongation of lead particles near the surface. Shearing along the strain marking occurred probably due to the oxidation of lead. The screening of the artefact at higher magnification (Fig. 19, 1500 X) indicated the presence of slip bands which was formed due to the subjecting of the Ring to hot working and/ or cold working.

This was supported by the presence of ‘Twin bands’ at a magnification of 1000 X (Fig. 18). Parallel strain marks parallel to outer surface of the ring were also seen present. Normally hot working or cold working and annealing heat treatments generate annealing twins in FCC metals like Copper.

The micro structural gleanings in region-II showed equiaxed grains of copper, alpha phase and twin bands with slightly elongated particles. Region - I shows top surface with extensive deformation where as region-II shows less deformation because of some excess metal protracted out of the contour of the ring. The micro structural details in the cross section indicate globular lead particles (200X) (Fig. 20), twin bands and equiaxed grains in its structure.

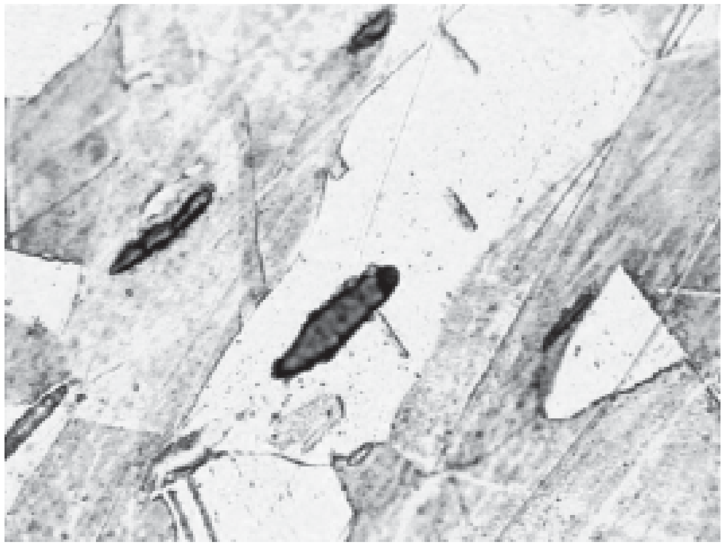


Fig. 18. Micrograph showing elogated lead particles, slip bands, 1500X

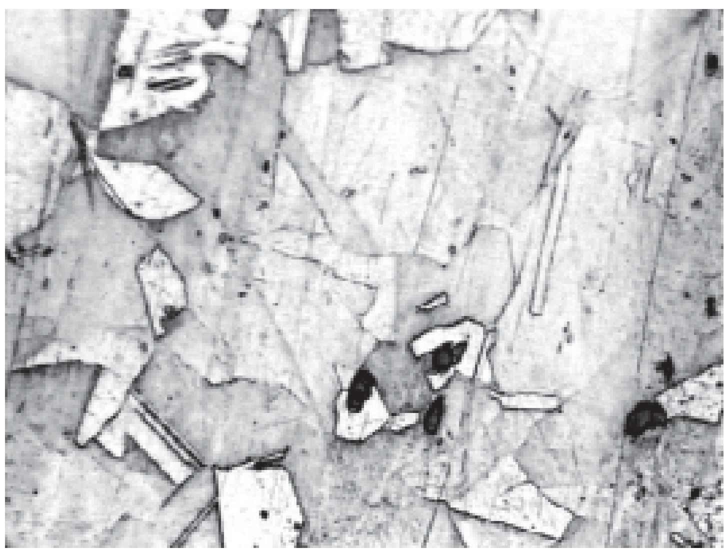


Fig. 19. Micrograph showing twin bands, 1000X

Iron Artefact

Adichanallur excavations brought to light fifty-five iron artefacts. The artefacts were in a highly corroded condition because of prolonged contact with earth for more than two thousand years. The iron artefact, an indeterminate object

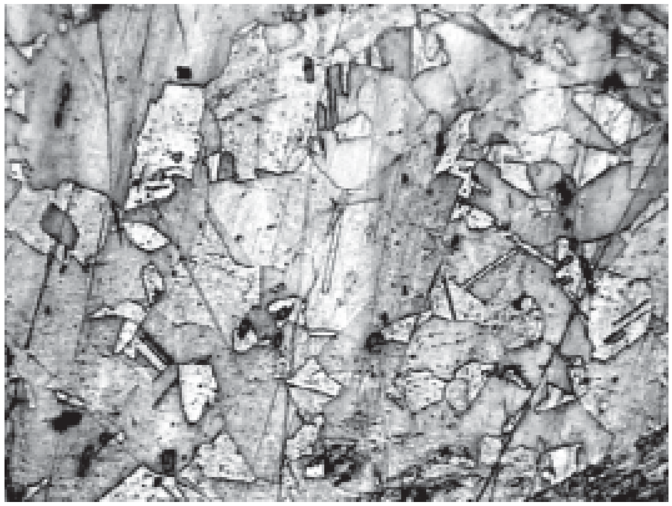


Fig. 20. Micrograph illustrating twin bands, globular lead particles and equiaxed grain structure, 200X

Fig. 21. Iron Piece, Physical appearance

(Sample no.54, fig.21) was taken up for study and it measures 16cm in length and 2cm in width.

Elemental Composition

The iron artefacts were analysed at RRL Laboratory, at Bhubaneswar for elemental composition. The resultant study indicated the presence of the following major elements, viz., Fe, Ti, C, V, Mn, Ni, Cu and P. Iron formed the major constituent with a percentage varying between 92 to 96%. Titanium formed the second major element with a content varying between 1 to 3 %. The presence of carbon varied between 0.1 to 0.5% indicating that the artifacts were low carbon steel. Ore samples collected from Adichanallur analysed at the ICP-MS Lab, NIOT, Chennai showed the presence of Fe, Ti, Mn, Zr, Sn, V, Mg, Cr and Ni. Titanium formed the second major element in the samples analysed and was varying between nine to 3%. Iron was found in the order of 46.77%. Manganese varied between 1.2 to 0.21%.

The compositions of the artefact taken up for study indicate the presence of elements mentioned in the table 5. The presence of Ti, V, Mn and Ni in ore as well as with the composition of the metal indicate that these elements were intrusive elements from the ore. Since Vanadium is a powerful detoxifier possessing alloying properties in steel, it gives high tensile strength and elastic limit. Its occurrence at 0.99% indicates that it would have helped the steel hardened from a higher temperature, without injurious effects, than plain carbon steel (Robert S. Williams, *et al*.1948).

Table 5. Elements in Wt%

Sample. No	Ca	Ti	V	Mn	Fe	Ni	Cu	P	S
Fe54	0.13	0.99	0.99	0.26	95.09	0.17	0.1	0.046	0.26

Metallographic Study

The iron piece was polished and etched with Nital to reveal phases in the artefact. The microscopic examination showed that the metal was in different stages of oxidisation viz., pure metal followed by partially oxidised and fully oxidised phase (Fig. 22).

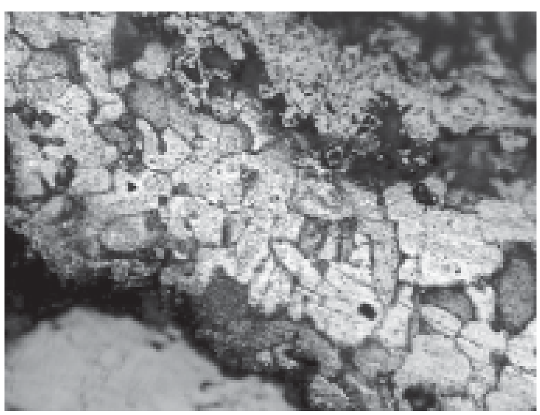


Fig. 22. Iron artefact in different stages of corrosion 200X

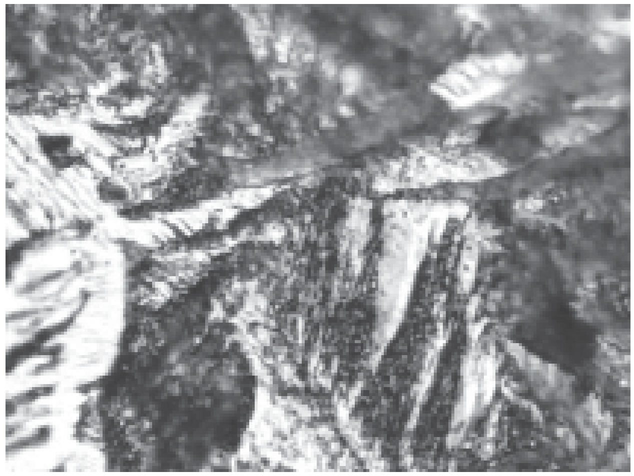


Fig. 23. Micrograph revealing bainitic Structure in the matrix, 1000X

Microstructural details showing bainitic phase (Fig. 23) indicate that the artefact underwent bainitic transformation due to a relatively fast (rapid) cooling from high temperature austenite phase either by cold air or by quenching with oil. Because of the presence of alloying elements in the steel, the formation of bainite during cooling from high temperature phase austenite becomes easier. The microstructure at the oxidised portion showed cracked corroded region of the steel (Fig. 24). Fully oxidised region revealed cracks due to stress probably due to buried condition for thousands of years (Fig. 25).

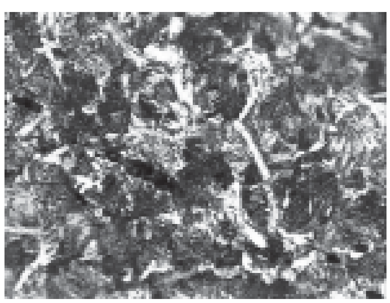


Fig. 24. Cracked corroded region, 200X

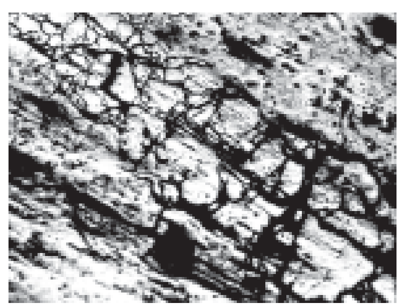


Fig. 25. Different stages of corrosion. Cracks due to stress? 100 X

Discussion

The Adichanallur burial site, covering an area of one hundred and fourteen acres, is the most extensive prehistoric burial site discovered in South India until date. The urns that were excavated by ASI during the year 2004 are the material confined to the sheared quartz vein adjoining the main Tirunelveli-Tiruchendur road. The preliminary study by the scientists from NIOT has revealed that the site is not a simple burial site but an extensive multi industrial mining centre where ores of copper, iron and gold were extracted. The use of the pits excavated during the mining for burial, may be contemporaneous or immediately after the mining of minerals from the site. The survey was able to establish some old workings for iron, copper and gold ores in the area. The Optically Stimulated Luminescence (OSL) dates derived from the samples gave a date ranging from 3400 ka to 1920 ka with an error margin of 23 to 18 %. The long time-lap of 1,500 years with ± 23% for the Adichanallur burials indicate that an abundant mineral wealth and its exploitation by the inhabitants from the Iron Age and succeeding periods. The exploitation of mineral by the miners is not restricted to Adichanallur and similar old workings were discovered by the scientists from the NIOT at Krishnapuram (8.680694N, 77.80644444E to 8.681306N, 77.80738889E). Further geo-physical survey in the adjoining area is required to understand the extent of mineral exploitation by the early metallurgists.

The study on early historic coins shows the use of tin in higher percentage. The elemental composition of the sieve from Kodumanal (Sasisekaran, et al. 2006) point to the use of tin and lead as an alloying element, though their percentage level were low, probably indicating their chronologically anterior time bracket, comparing to the tin rich copper alloy, in the south Indian context.

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