Late Bronze Age (Colchian) copper production in the Lechkhumi region

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ABSTRACT: Two reconnaissance expeditions from the Georgian National Museum, in 2013 and 2014, established that the Lechkhumi Caucasian mountain region was exploited for copper during the late Bronze Age. This region is also central to the legendary late Bronze Age visits to Colchis (western Georgia) by Jason and the Argonauts, mentioned in Homer's Odyssey and recounted in more detail by Apollonius of Rhodes. In 2016-2018 exploratory work plus more detailed archaeological, analytical and geological investigations at the Dogurashi group of sites north-east of Tsageri showed these as being active during the 13th-9th centuries BC. This group of three Dogurashi sites is being investigated as is the associated ore extraction. Previously this industry was known only from chance discoveries of metalwork hoards which included broken-up copper ingots, smaller copper alloy cakes and finished artefacts.

Introduction and background

Surviving artefacts and snippets of information in early written sources indicate the exploitation of copper ores in various parts of the Caucasus region since the early Bronze Age. Much of the associated metalwork has been analysed, particularly those artefacts associated with the 4th-3rd millennium BC Kura (Mtkvari)-Araxes culture of eastern Georgia (Abesadze 2011) although the production (smelting) sites associated with early to middle Bronze Age Caucasian copper alloy metalwork have yet to be identified.

Colchian (early western Georgian) metalworking traditions of the late Bronze Age became famous firstly through semi-legendary voyages to the SW part of the Caucasus mountain region by Jason and the crew of the Argo in the later 2nd millennium BC as mentioned in Homer's Odyssey and further described by Apollonius of Rhodes (3rd century BC); the Argonauts reportedly saw Prometheus (the Titan) chained with bronze fetters to one of the mountains of this region (which is still a local tradition). Following later speculation, the Greco-Roman scholar Strabo (*c*64BC to AD24) suggested:

> '... the wealth of the regions about Colchis, which is derived from the mines of gold, silver, iron and copper suggests a reasonable motive for the expedition, a motive which induced Phrixus also to undertake this voyage at an earlier date.'(Jones 1917, Vol I, 2, 39).

Little is known before the mid-1st millennium BC although the sophistication of late Bronze Age Colchian society is hinted at by a record of the Assyrian king Tukulti-Ninurta I (1245-1209 BC) that mentions the existence of '40 kings by the Upper [Black] Sea' (Rayfield 2012, 15).

Copper sulphide ores become oxidised to form the distinctive, more easily smelted, copper minerals that early miners would have looked for, in particular blue and green hydrated copper carbonate minerals, azurite ($Cu_3(CO_3)_2(OH)_2$) and malachite ($Cu_2(CO_3)(OH)_2$), and copper oxides tenorite (CuO) and cuprite (Cu_2O). It is assumed these were the ores exploited by the Kura (Mtkvari)-Araxes culture (Sagona 2018, 218), whose main copper smelting areas appear to have been in SE Georgia. Ore bodies near the surface would have remained composed largely of sulphide minerals, particularly chalcopyrite (copper-iron sulphide). For this reason it only became practicable – on least on any significant scale – to smelt these extensive (but widely dispersed) ore deposits during the late Bronze Age once copper smelting technology became sufficiently advanced to make this possible (Chernykh 1992, 60). Although polymetallic ores rich in copper are very widely dispersed in Georgia, even by the early 20th century the main three areas for copper exploitation were all in the south of the country (Ghambashidze 1919, 24).

The western Georgian region that became known as Colchis does not appear to have been a major copper smelting area until the late Bronze Age, possibly because of the lesser availability of weathered sulphide ore deposits in the Greater Caucasus. Smelting un-weathered chalcopyrite ore to produce copper yields much greater quantities of slag, the stony waste by-product of the process (Craddock 1995, 146-9), than smelting oxidised ores. Surviving waste tips of this bulky and durable material make finding late Bronze Age smelting sites much more likely, especially where these have been disturbed by later human activities or erosion. Evidence for late Bronze Age copper production across western Georgia has accumulated steadily over the past hundred years with many chance finds of surviving contemporary metalwork coming mainly from votive hoards. However almost nothing was known of late Bronze Age production sites.

This changed after the Second World War when the hilly zones of the Black Sea coastal region were exploited for tea plantations under the Soviet collective farm system. A previously unsuspected late Bronze Age copper smelting industry was discovered. Large numbers of sites, relatively small in individual scale, were found scattered across the region from the lower

Figure 1: General location map showing the modern state of Georgia (east of the Black Sea) with the region of Lechkhumi shown shaded in the upper left centre.

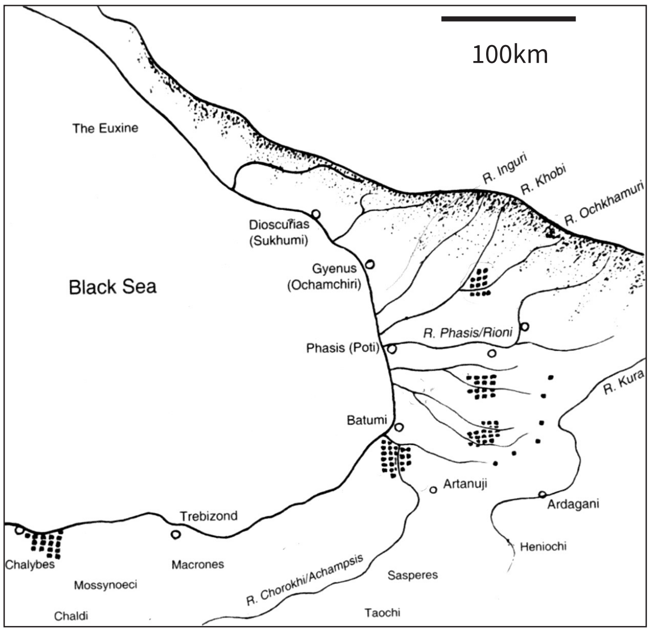

Figure 2: Sketch map showing the main groups of early smelting sites found during large scale survey work, mainly in the 1970s and early 1980s. Of particular interest is the group of sites in the hilly zone to the north near the Ochkhomuri River (after Khakhutaishvili 2009, 20).

Chorokhi River near Batumi on the Black Sea coast to the Ochkhomuri river valley near the main Caucasus Mountains to the north (Figs 1 and 2). During the 1960s archaeological survey began to record the whereabouts of these sites, and by the mid 1980s some 400 sites had been noted and 35 had been excavated. However this ambitious, large-scale programme of survey and partial excavation was never completed and only an interim report was published although contemporary scientific (radiocarbon and archaeo-magnetic) dating indicated that the industry operated between about 1800 BC and 600 BC (Khakhutaishvili 2009).

Curiously, this was interpreted as evidence of a widespread, exceptionally early iron smelting industry, perhaps because of the repeated finding of iron rich slag on the sites. This slag was actually the by-product of exploiting polymetallic (iron/copper/zinc) ores from across this region. However at the beginning of more recent survey work to re-examine the earlier findings in the Guria region (east of Poti on the Black Sea coast; Fig 2), inspection of the slag from these sites showed it to be residual waste from a previously unsuspected but widespread late Bronze Age copper smelting industry (Gilmour *et al* forthcoming; Erb-Satullo *et al* 2014). The ore sources for this are still unknown but are suspected to be chalcopyrite-rich deposits situated in the mountain areas local to each group of sites, although these ore sources still await discovery (Gilmour *et al* forthcoming).

Previous studies of the Lechkhumi region

Archaeology

Lechkhumi is a little studied region of Georgia just west of the Rioni river (cf Figs 1 and 3) and most reports of early metal working remains come from geologists and others visiting the region. Minor archaeological expeditions were conducted in the village Tskheta in 1962 and in also the environs of villages Tskheta and Dekhviri in 1970-71, 2012 and 2014-16. In spite of the limited character of these investigations, the findings are important as they indicate settlement in Lechkhumi from the late 2nd millennium and during the 1st millennium BC and later. However early legends and past chance artefact discoveries in the area together imply the former existence of a prehistoric copper/bronze industry in this mountainous area of the Tskhenistskali and Rioni river basins (Fig 3). Before the current project no early metallurgical sites had been identified here but the potential of this region was clear from earlier accidental discoveries of many transitional late Bronze Age/early Iron Age copper or copper alloy artefacts, particularly 12 metalwork hoards mostly now in the municipal museum of Tsageri, the town central to this area (Figs 3 and 4).

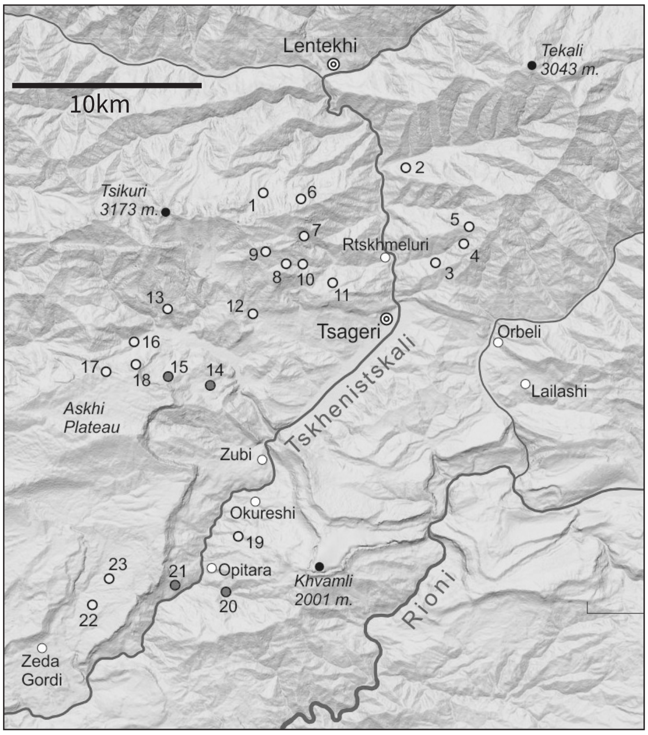

Figure 3: Map of western Lechkhumi showing the archeometallurgical sites surrounding Tsageri (cf Fig 1). The numbered dots are late Bronze Age copper-smelting sites, except 14-15 and 20-21 which are medieval iron smelting sites encountered during the survey. 1: Lashkili, 2: Gvimbrala, 3: Dogurashi I, 4: Dogurashi III, 5: Dogurashi II, 6: Samreki, 7: Letsperi 1, 8: Letsperi 2, 9: Letsperi 3, 10: Letsperi 4, 11: Shavbinula, 12: Chikelashi, 13: Gverdistavi, 14: Kvatsiteli, 15: Namcheduri, 16: Mushulda, 17: Gabonalia, 18: Punatskhvari, 19: Okureshi, 20: Opitara, 21: Ladzgveria, 22: Tsmindaliani, 23: Kadari.

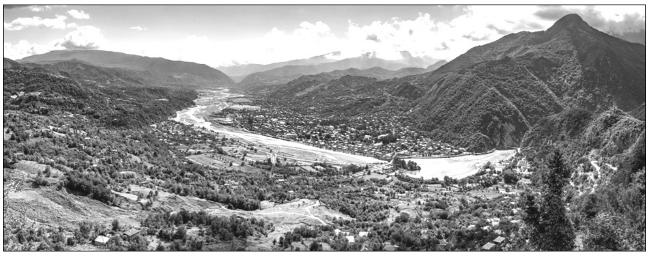

Figure 4: View looking south-west across the Tskhenistskali river towards the town of Tsageri from the adjacent mountain ridges to the south of the Dogurashi area. The Rioni river basin lies to the east (left) of this view.

These chance finds included various finished artefacts of copper/bronze – and a few of iron – including axes, knives, hoes and other tools, but also small figurines and decorative items (Sulava *et al* 2012 , 19-31). From these finds this we can see both the variety and concentration of late Bronze Age Colchian material in the Lechkhumi region. Particularly iconic are the many, typically Colchian axes (Figs 5a-5c), often elaborately shaped and highly decorated. Other finds include copper ingots(originally weighing up to 60kg or more but usually broken into roughly fist-sized pieces (Fig 5d)), smaller cakes from subsequent working, plus metallurgical production debris, slag, coarse crucible remains, tuyères (air delivery pipes), furnace wall fragments and other related waste debris, as well as sherds of typical prehistoric Colchian ceramics. Traces of secondary metallurgical workshop activity sometimes occur in settlements, for instance the encrusted casting fragments for a fylfot (swastika) form of Colchian bronze buckle from Tskheta (8th-5th centuries BC). Votive hoards are common and include copper ingots, cakes, finished artefacts (in some cases possibly made for deposition) and occasionally slag (Sakharova 1966; 1976; Sulava 2001a; 2001b; 2003; 2008).

Archaeometallurgy

Early discoveries of prehistoric archeometallurgical artefacts in Lechkhumi have been made in the vicinities of Opitara, Lachepita and Okureshi villages (Fig 3) where copper ore occurences, smelting (slag) debris and metalwork (ingots) have also been reported (Jessen 1935; Sakharova 1966) although without further details. One early report mentions 'huge heaps' of copper slags and backfilled pits but little other detail (Gobejishvili 1962). More recent sightings suggest these observations are overstated and that the slag heaps are similar to those seen during recent reconnaissance work.

Lechkhumi emerged in the earlier 20th century as

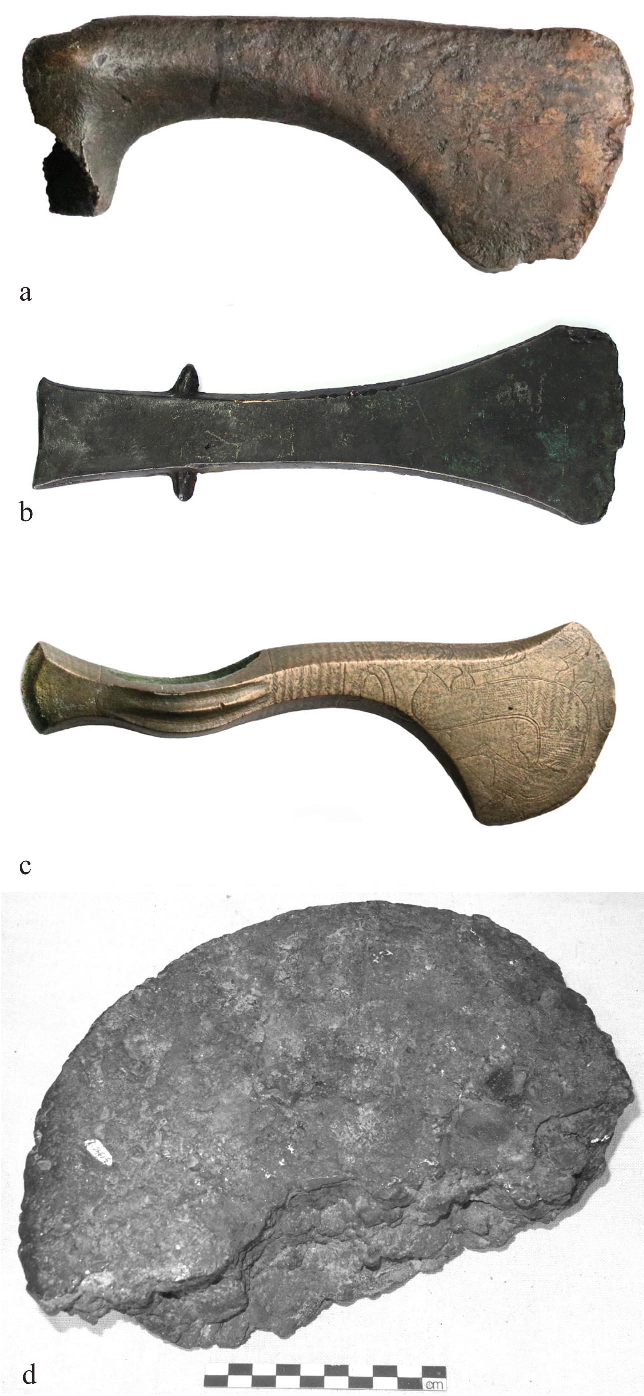

Figure 5: Copper alloy finds from votive hoards in the Tsageri area now in Tsageri Museum. a) a proto-Colchian axe from Orbelli (early 2nd millennium BC), b) a Colchian flat axe from Okureshi, c) an elaborately decorated Colchian axe from Tskheta (both transitional late Bronze Age/early Iron Age), and d) a broken-off fragment of a roughly plano-convex copper ingot. Lengths: a) 124mm, b) 189mm, c) 186mm.

an area attracting geologists prospecting for metal sources such as the Mekvena and Opitara ore deposits (Kalandadze 1931). Previously geologists had drawn attention to slag dumps and ore occurrences at Opitara (Bezhanishvili 1933; Bartholomeev 1907). Other contemporary geologists working in this area also reported large quantities of slag, pottery sherds and ‘bronze’ ingots in the vicinity of Opitara, at Lashegele, Tetrigele, Tetritskaro and Okureshi, and also around Kinchkha (Togonidze 1933).

In 1938, based on the macroscopic and microscopic investigations of slags from Racha and Lechkhumi, an engineer visiting the area deduced that the slags were consistent with copper smelting. He concluded that prehistoric copper smelting existed in Racha and Lechkhumi but that ore mining was small-scale and primarily of local importance, being related to limited ore exposures at the surface (Topuria1938).

Place names

Many toponyms (place names) in Lechkhumi are of Svan or Megrelian origin. Svan is the language spoken in the mountainous region of Svaneti to the N and NW of the modern district of Lechkhumi, while Megrelian is the language spoken in the western Georgian regions of Samegrelo and Abkhazia to the W of Lechkumi. Some local toponyms are associated with metallurgical production and mining in this region, for instance Dekhviri, Kveregverdi, Kvereshula and Sakveria all share the same root word ‘Kver’ a word of Svan origin meaning hammer. Similarly we have Kvatsiteli (red stone), Namcheduri (smithing place) and Lashkili (sound of the smiths), all indicative of much earlier metalworking and production (Mamardashvili 2010). The local Lechkhumi name for slag is ‘Nashkiduri’, derived from the same Svanish word meaning forging. Various other local place names are similarly descriptive in nature and also are of Svan origin; a detailed study of these forms part of this project to look for echoes of earlier metallurgical activities.

Geology

According to one metallogenic subdivision scheme for this part of Georgia (Fig 6), prehistoric archaeometallurgical sites of Lechkhumi are concentrated in the Racha-Svaneti metallogenic district which is the metallogenic belt of the southern slope of the Greater Caucasus and include Kvemo (lower) Svaneti and Racha-Lechkhumi ore fields (Tvalchrelidze 1961; Janelidze 1965; Geguchadze *et al* 1976; Academy of Sciences 1958). Hypogene copper-pyrrhotite base metal deposits of Lechkhumi occur in Lower and Middle Jurassic volcanic and volcano-sedimentary rocks and cross-cutting igneous hypabyssal bodies (Beridze 1983; Janelidze 1965; Topuria 1938; Ivanitski and Vezirishvili 1954; Nadiradze *et al* 1973; Anon 1974).

The Dogurashi archeometallurgical sites lie within the Rtskhmeluri ore district of the Kvemo Svaneti ore field (Fig 6). This includes several copper(-iron) and lead-zinc ore occurrences noted at Dogurashi, Nargvevi, Silis-gele, Jojokheti, Sareki, Kvedreshi and other nearby places. Ores from Rtskhmeluri mainly comprise pyrite, sphalerite, galena and chalcopyrite. Pyrrhotite, fahlore (complex metallic sulphide minerals) and native gold are also associated with them. Antimony, silver and arsenic minerals are present in minor amounts. Supergene (near surface) minerals are represented by iron, copper, lead, zinc, arsenic and antimony secondary minerals (Ivanitski and Vezirishvili1954; Nadiradze *et al* 1973; Anon 1974). Reported historic grades for the Rtskhmeluri group of ore deposits and occurrences are 0.06-0.6% Cu, 0.5-6.26% Pb and 0.63-6.75% Zn (Geguchadze *et al* 1976). The deposits were regarded as low-temperature hydrothermal deposits (Ivanitski andVezirishvili 1954).

Georgian geological reports mention more than 200 copper, arsenic, antimony and polymetallic deposits and their surficial exposures (Anon 1970). Traces of ore mining and processing can be identified in almost all major deposits. In particular, to such regions (of the Greater Caucasus) are attributed Abkhazia, Racha, Kakheti (Zemo Alazani) mining-metallurgical sites and (for the Lesser Caucasus) the Bolnisi-Dmanisi and Achara-Guria sites. Included in this single northern geographic distribution area are the Abkhazia, Svaneti and Racha zones of copper mineralization, systems which run from the western part of the main Caucasus range to the east as discontinuous deposits.

Prehistoric copper smelting sites

Two short exploratory field survey expeditions were mounted in the Lechkhumi area in 2013 and 2014, centred on the Tskhenistskali river valley and the town of Tsageri (Figs 3 and 4), whose museum displays chance finds of late Bronze Age metalwork and copper smelting debris. Local knowledge enabled the discovery of seven prehistoric copper smelting sites – and three more have been found more recently – marked by waste dumps each with many tonnes of slag. These sites also imply the existence of local mine shafts or pits for the extraction of unweathered polymetallic sulphide ores, although these are very difficult to find, but hard rock mining plus fire-setting are both likely to have been involved.

The exploratory expeditions laid the basis for the

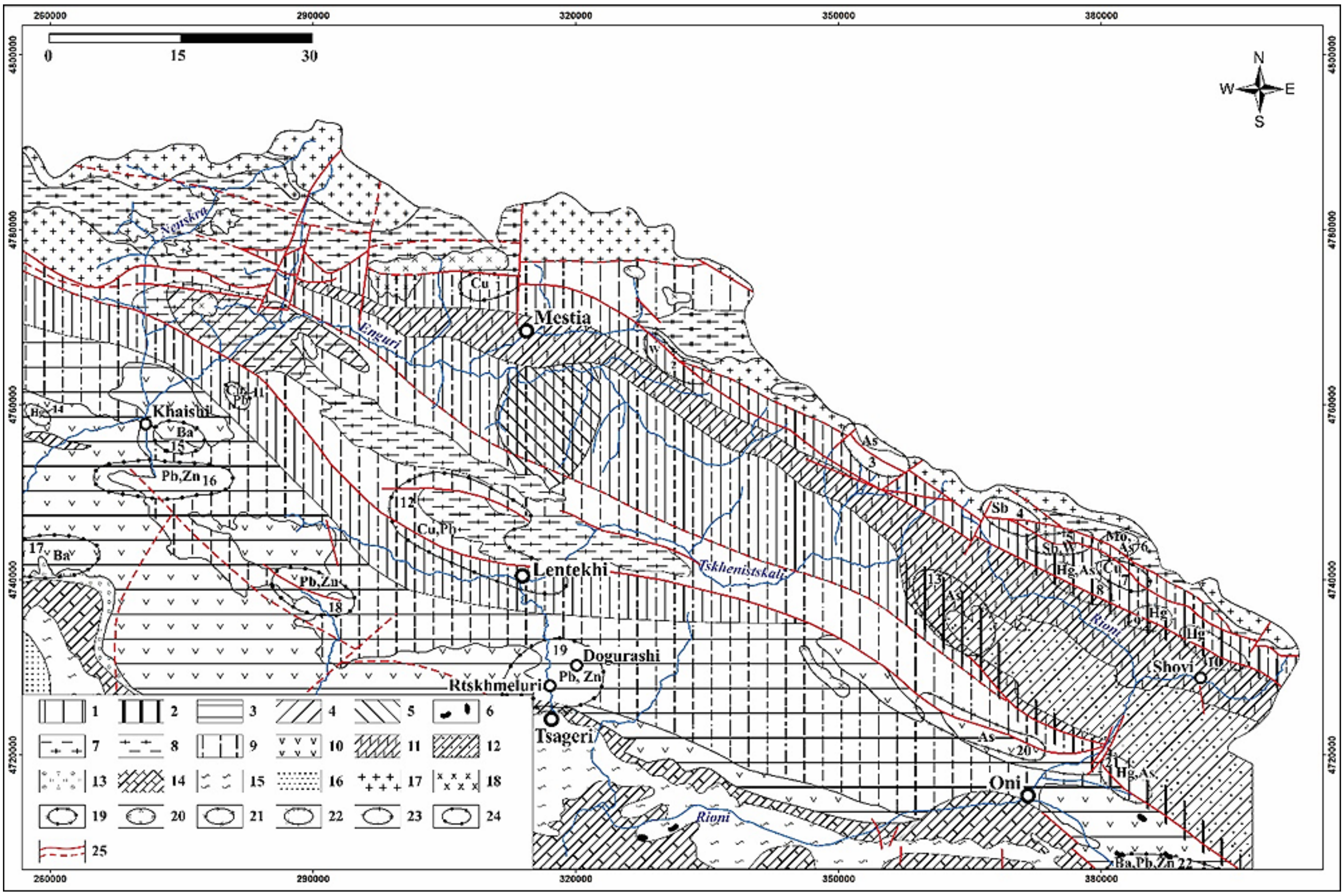

Figure 6: Metallogenic sketch map of the southern slope of the Greater Caucasus. Tsageri is centre bottom (cf Fig 3). Key: 1-6: Ore belts and distribution areas of mineral resources, 7-16: Sedimentary-metamorphic, sedimentary and volcanogenic-sedimentary formations, 17-18: Magmatic rocks, 19-24: Ore fields, 25: Tectonic displacement lines (after Geguchadze et al 1976). Scale bar 30km.

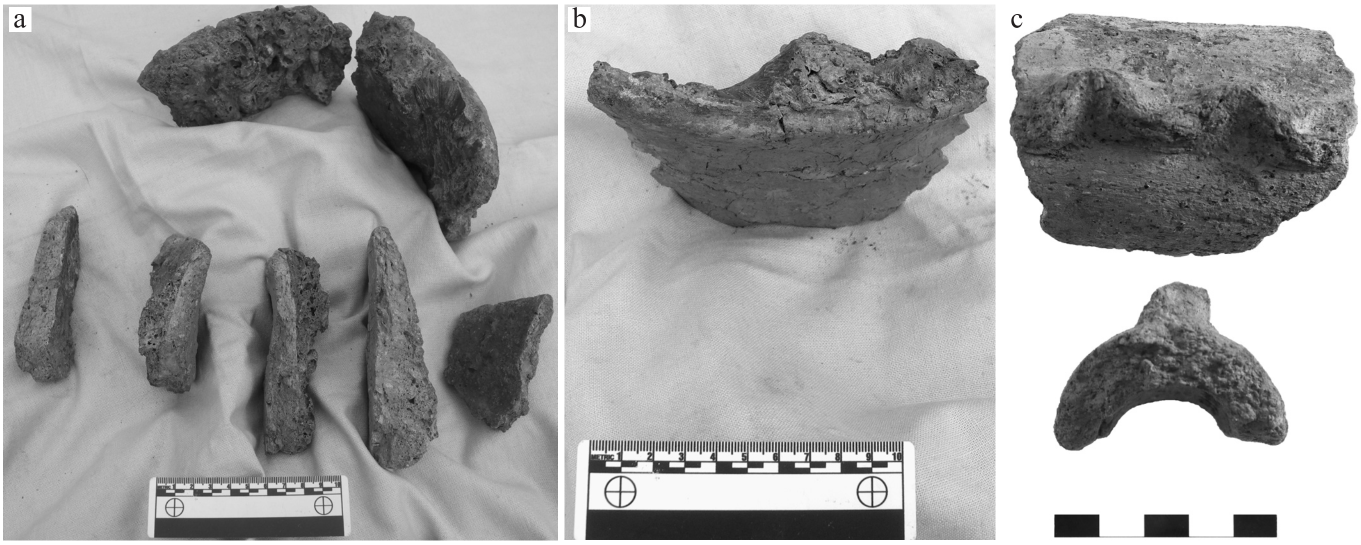

Figure 7: Industrial ceramic fragments from Dogurashi I. a) coarse grey-fired crucible fragments, most are both heavily vitrified and slag encrusted on the inside; b) one of the fragments with the slag clearly visible; c) a typical fragment of red-fired tuyère (air delivery pipe), here with an applied snake-like decoration (possibly to propitiate the smelt), plan and section views. All scales cm divisions.

current programme of survey, excavation and geological prospection of the Dogurashi area. Apart from the ten early copper smelting sites so far located, many others must exist, and searching for these is a target for future work. Finding such sites is difficult even when on top of them, although they tend to be on mountain terraces where smelting was possible. The mountain terrain is difficult and we may expect the smelting sites to be located near the ore sources, where there are good supplies of wood for charcoal which acts as both fuel and the reducing agent for smelting.

Early copper exploitation

Topography and geophysics

Three sites NE of Tsageri were identified (Fig 3, 3-5). Dogurashi I is situated on a narrow sloping terrace above a steeper drop to the stream below. Recent erosion at the edge of this terrace had exposed the upper part of the slag tip associated with copper smelting. Archaeological investigation suggests that the terrace was once larger and more practical for smelting work, but that the eastern side of the terrace, including any smelting furnace(s), have been lost to erosion. Excavation work here was begun in 2016 and finished in 2018.

Dogurashi II lies at 1,075m above sea level, about 200m higher than Dogurashi I, and is a similar but much better preserved site, though consequently was much more difficult to find. Nothing was visible on the surface apart from a few fist-sized lumps of copper smelting slag similar to those found at Dogurashi I and typical of all the early copper smelting slag from this area.

Later a third copper smelting site, Dogurashi III, was found by chance next to a mountain track between the two other Dogurashi sites, on a small terrace about 25m wide situated at height of about 1,000m. A magnetometer (gradiometer) survey carried out here in September 2018, near the centre of the terrace, indicated the site was better preserved than expected.

Dogurashi I

Dogurashi I was located in a densely tree-covered mountain area approximately 7km NE of Tsageri, east of the Tskhenistskali river and near the right bank of the tributary Dogurashis-gele (Fig 3). It had been exposed by erosion of the topsoil of the woodland-covered mountainside. It lies on a narrow sloping, SW-facing natural terrace about 40m uphill from the bank of the Dogurashis-gele stream. This is the first prehistoric copper smelting site excavated in the Greater Caucasus mountain area of Colchis and findings so far indicate it to be different from transitional late Bronze Age/early Iron Age smelting sites excavated elsewhere across western Georgia. The site survives less well than first hoped although much of the main waste tip survives despite some erosion. Part of the slag dump was excavated and found to contain large amounts of copper smelting waste including fragments of earlier furnaces, tuyères, fragments of large, coarse grey fired crucibles and smelting slag, all mixed together with much black ashy/cindery material (Fig 7).

We do not know how much chalcopyrite ore was smelted at Dogurashi I, although this may be roughly gauged from the slag surviving from the smelting. The total volume of slag is somewhere around 15-20 cubic metres,

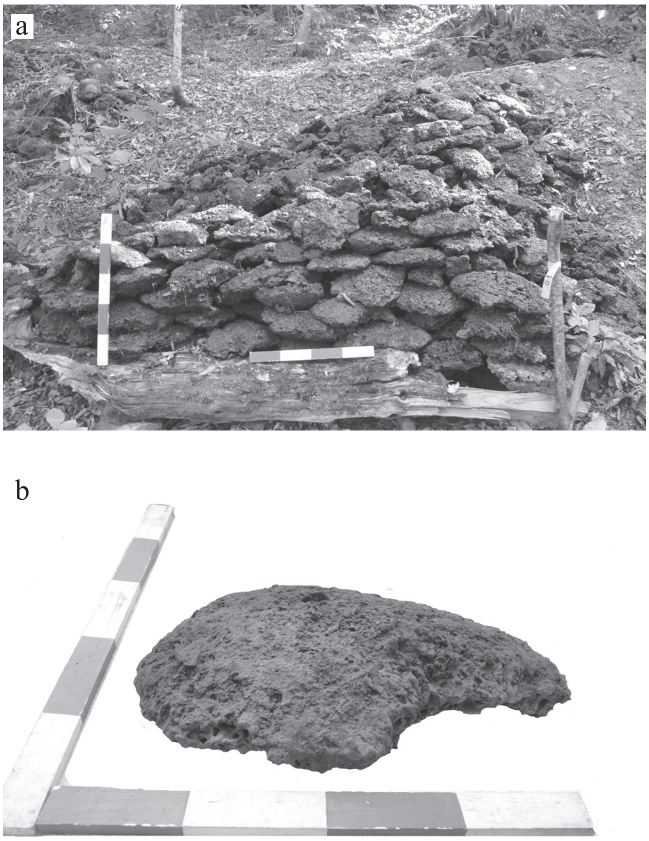

Figure 8: a) Large slag lumps excavated from Area 1 at Dogurashi I, b) A typical complete large plano-convex slag block with its curved base uppermost (scale bars with 100mm divisions).

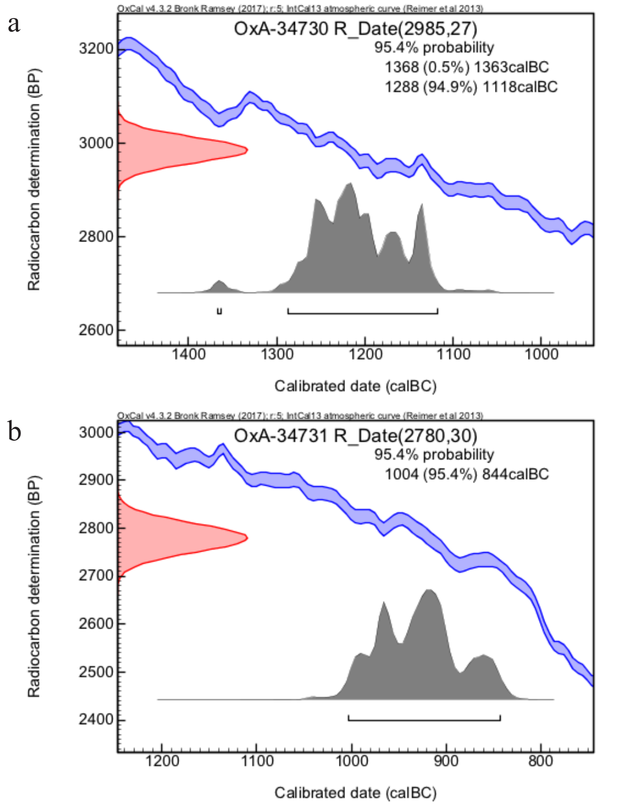

Figure 9: Radiocarbon dating plots from two charcoal samples from Dogurashi I. a) sample relating to the early use of the probable ore roasting hearth, and b) from inside a slag block relating to a later phase of smelting on the site.

*c*20-25 tonnes depending on density (Fig 8) although this may be an under-estimate. Given the local abundance of wood to provide charcoal for fuel, together with the effort required to move heavy material in difficult terrain, the mines are suspected to lie nearby though are yet to be identified.

Excavation work began next to the terrace edge and stratified archaeological levels were found to be between about 1.0 and 2.5m deep (Rezesidze *et al* 2018). Many campaigns of smelting had been carried out and the site had been remodelled at some point although it was impossible to determine whether or not there were lengthy periods between the smelting campaigns. Laboratory investigation of the (generally) porous slag showed the matrix to consist mainly of iron silicate (fayalite) together with fragments of unreacted ore and silica plus small pieces of copper metal and other burnt waste.

No evidence of a smelting furnace survived at Dogurashi I, nor any traces of other working areas/functions (such as ore crushing/sorting or fuel preparation) apart from the rubble-covered remains of a roughly bath-shaped, probable roasting hearth and a small adjacent area towards the scarp edge where two large stones were found, possibly the remains of a bellows emplacement. Underneath the collapsed rubble the base of the hearth was filled with a mixture of slag, fragments of ore-bearing rock and included a fragment of tuyère embossed with moulded snake-like decoration, perhaps intended to help to improve the chances of a more successful the copper smelting campaign (Fig 7c).

Magnetometry showed no additional traces of smelting-related activity across the steepening hill-slope above the terrace. Any other working areas, smelting furnace(s) and slag tip have been lost to erosion down the steep hill-slope towards the Dogurashi-gele stream. Radiocarbon dating of charcoal samples recovered from both a scatter relating to the use of the roasting hearth and from one of the larger slag blocks indicate that the site was in use between the 13th and 9th centuries BC (Fig 9).

Dogurashi II

This site lies on a NW-facing mountain terrace at approximately 1,075m (above sea level). The terrace is quite large and flat, measuring about 60m wide and 30m from front to back. It is relatively open as it has recently been cultivated. Magnetometry (gradiometry) over the NW half of the terrace showed the ancient copper smelting site lay near the edge of the terrace covering an area approximately 10m across with the slag dump extending down the hill slope.

Using the information revealed by magnetometry, excavation near the NW corner of the terrace revealed the upper part of the slag tip at the edge of the terrace where it fell away down this part of the mountain. A thick topsoil layer (0.30m) had built up over many centuries and was deep enough that recent cultivation had not disturbed the underlying smelting remains.

Underneath the relatively slag-free topsoil the darker subsoil contained much copper smelting slag, crucible fragments and related debris plus charcoal. The terrace appears to have been used intermittently for agriculture in recent centuries and this activity disturbed parts of the much earlier smelting site. Hollows in the underlying smelting site had become filled with a much paler, sterile slag- and cinder-free accumulation which appears to have built up slowly over many centuries indicating that after smelting ended the site was abandoned and disused for a long time.

The final phase of copper smelting is represented by a very dark layer full of slag and other waste filling the remains of a probable ore roasting hearth (Fig 10), extending towards the edge of the terrace and then tipping downhill. Associated pottery indicates a transitional late Bronze Age/early Iron Age date for the smelting but forthcoming radiocarbon dates from charcoal samples should clarify this.

Figure 10: View looking east across the 4m-wide Area 1 at Dogurashi I towards the remains of a suspected roasting hearth. The section is a clear stratified sequence: at the bottom is the thick dark slaggy backfill of the hearth, above that a clean brown abandonment horizon showing disuse for many centuries, then dark slaggy material possibly used to level the terrace for later agriculture and, uppermost, the more modern topsoil build-up which is almost slag-free. See also back cover.

Dogurashi III

The smelting site of Dogurashi III lies roughly midway between Dogurashi I and Dogurashi II and was discovered by chance in 2016 while walking between sites when small fragments of copper slag were noticed around the track. This site is on a small, generally west-facing 30m by 20m terrace. The central part of the terrace was cleared for a magnetometer survey which showed the smelting site to survive better than expected (Fig 11). The largest magnetic anomaly – a possible furnace – was found in the centre of the low rise near the middle of the terrace, with the slag dump fanning out downhill.

Figure 11: Looking south across the working area of the copper smelting site Dogurashi III with geophysics underway.The survey suggests that a possible smelting furnace lies beneath the apex of the low mound with slaggy waste tipped to the west (right) down the mountainside.

Late Bronze Age copper from the Lechkhumi region

Apart from traces of metal in slag, no copper has yet been recovered from any Lechkhumi smelting site. However there have been regular local chance finds of copper ingot fragments, usually broken into roughly fist sized pieces or more complete hemispherical lumps. Sometimes these are stray finds but are often found as parts of groups forming recognisable 'hoards', most probably votive offerings of the transitional late Bronze Age/early Iron Age. Energy dispersive X-ray fluorescence (XRF) analysis of metalwork samples from the Tsageri area included 'ingot' fragments, smaller secondary 'cakes', as well as artefacts. Table 1 shows the copper of the ingots, cakes and some of the artefacts contained minor impurities with between about 0.5-2.5% iron, zinc under *c*1%, arsenic up to *c*0.5%, lead up to 0.3% and nickel and antimony up to *c*0.2%. These results are consistent with interim semi-quantitative XRF results from slag samples from the copper-smelting sites recently located around Lechkhumi.

The smelting slags are rich in iron, often zinc, and contain variable amounts of copper plus some lead (and manganese) and other minor impurities. Only iron and zinc have been found in more than minor impurity levels in the slag, with iron being consistently high and zinc variable but often high. This reflects the polymetallic nature of many ore deposits across this region (Ghambashidze 1919, 23-48). Iron and copper were present in these ores as chalcopyrite (copper-iron sulphide) with varying amounts of zinc sulphide (sphalerite) and some lead sulphide (galena). Smelting these chalcopyrite ores must in part have been a crucible process given the large amounts of coarse grey crucible fragments found in the waste slag dumps. Most crucibles were large, roughly bowl-shaped vessels, heavily vitrified on the inside, often measuring *c*0.30m in diameter. A two-stage production process involving initial roasting and smelting of the ore to yield copper sulphide 'matte', followed by final smelting to produce copper seems probable. Iron was important to the success of the process as this combined with the rocky waste component (gangue) of the ore, removing it mainly as iron silicate.

Final smelting probably yielded metallic copper varying in size between pea-sized pieces and larger blobs similar to the copper collected together for re-melting much earlier (3rd millennium BC) at Khirbet Hamra Ifdan, Jordan and Shahdad, Iran (Hauptmann 2007, 241). Copper from Colchian late Bronze Age smelters may have been collected for re-melting to yield the large ingots, mostly later broken up into fist-sized lumps for trading and subsequent artefact production. Many fragments of the deep, plano-convex copper ingots have been found; they were typically 100mm in depth and when complete would mostly have been 150-250mm in diameter, typically weighing 30-60kg. According one report, shepherds in the Dogurashi area in the 1890s found nine large ingots – perhaps from a single votive deposit – and sold them for scrap.

Geological investigation of the ore sources

In 2017-2018 a geological survey focused on the adjacent localities of Dogurashi and Nargvevi as they host possible source ore deposits for the local Dogurashi prehistoric copper smelting sites. Ore sources are likely to be of local origin given the difficult topography of the Lechkhumi area for the transportation of ores

Table 1: Energy-dispersive X-ray fluorescence analyses of metal samples from Tsageri Museum, Lechkhumi (wt%)

Description	Inventory no	Lab no	Fe	Co	Ni	Cu	Zn	As	Ag	Sn	Sb	Pb
Complete hemispherical copper ingot	3-1976:1	HM1022a	2.68	nd	nd	96.1	0.95	0.12	0.07	nd	nd	0.06
Half hemispherical copper ingot	3-1940:2	HM1023a	0.76	nd	nd	98.9	0.64	0.16	0.10	0.05	nd	0.09
Hemispherical copper ingot, minus edge	3-1935:5	HM1024a	1.02	0.04	0.10	98.7	0.10	nd	nd	nd	0.14	0.03
Segment of copper ingot	3-1939:4	HM1025a	0.39	0.03	0.10	99.1	0.10	0.24	0.08	nd	nd	0.07
Segment of copper ingot	3-1976:3	HM1026a	0.14	0.02	0.07	99.6	nd	nd	0.08	tr	tr	0.03
Rough sector of copper ingot	3-1940:8	HM1027a	1.19	0.04	0.09	98.0	0.33	0.14	0.04	0.07	nd	0.06
Rough sector of copper ingot	3-1976:14	HM1028a	1.68	nd	nd	97.5	0.37	0.06	0.09	0.07	nd	0.23
Greater fragment of copper cake	1701	HM1029a	1.12	0.02	0.14	98.5	nd	nd	0.09	nd	nd	0.16
Lesser fragment of cake	17-- (?)	HM1030a	1.90	0.02	0.04	96.8	0.23	0.47	0.08	nd	0.15	0.32
Complete small hemispherical copper ingot	3-1976:13	HM1031a	0.11	0.01	0.05	99.7	tr	nd	0.05	nd	0.08	0.05
Sector fragment of copper ingot	3-1939:9	HM1032a	0.74	0.02	0.04	98.3	0.45	0.12	0.12	nd	nd	0.19
Mostly complete hemispherical copper ingot	3-1978:6	HM1033a	2.07	0.05	0.07	97.7	tr	tr	0.10	nd	nd	nd
Irregular, smooth copper block	3-1976:7	HM1034a	1.28	0.02	0.04	98.3	tr	0.18	0.06	nd	0.08	tr
Nearly complete 'bun'-shaped cake - 3 layers	3-1976:12	HM1035a	0.12	0.03	0.19	99.0	tr	0.47	0.04	nd	0.16	nd
Half a roughly 'bun'-shaped copper cake	?1700 series	HM1036a	1.32	0.03	0.15	92.3	0.29	0.10	0.05	0.05	0.14	5.59
Edge fragment of hemispherical copper ingot	?1700 series	HM1037a	0.84	nd	nd	98.4	0.61	nd	nd	0.06	0.07	nd
Edge fragment of hemispherical copper ingot	3-1976:11	HM1038a	0.89	nd	nd	98.0	0.69	0.05	0.06	nd	0.08	0.29
Neat cut quadrant of flattish copper ingot	3-1976:1	HM1039a	1.09	nd	nd	98.4	0.46	nd	0.07	nd	nd	nd
Bridle-bit from Tsagera horde	5-1938:??	HM1040a	0.03	nd	nd	93.4	0.55	nd	0.26	0.91	nd	4.83
Votive hoe from Tsagera hoard	5-1938:??	HM1041a	0.81	nd	nd	98.8	0.41	nd	nd	nd	nd	tr
Votive decorated axe from Tsagera hoard	5-1938:??	HM1042a	nd	nd	nd	89.2	nd	0.29	0.13	9.85	0.28	0.28
Votive decorated axe from Tsagera hoard	5-1938:3	HM1043a	nd	nd	nd	90.2	tr	1.33	0.05	7.01	0.14	0.36
Cast copper alloy dish from Tsagera hoard	5-1938:2	HM1044a	nd	nd	0.05	98.8	tr	0.57	0.13	0.07	0.19	0.23
Votive axe fragment from Tsagera hoard	5-1938:??	HM1045a	0.03	nd	0.05	97.8	tr	1.05	0.15	nd	0.30	0.62
Votive axe fragment from Tsagera hoard	5-1938:??	HM1046a	0.30	0.02	0.09	99.2	tr	tr	0.07	nd	0.11	0.22
Votive hoe from Tsagera hoard	5-1938:??	HM1047a	0.30	nd	0.03	97.7	tr	1.32	0.11	nd	0.24	0.26
Votive hoe from Tsagera hoard	5-1938:??	HM1048a	0.19	nd	0.03	98.2	tr	1.01	0.12	nd	0.14	0.30
Irregular copper cake fragment	5-1938:23	HM1049a	2.13	nd	nd	97.7	tr	nd	0.08	0.06	nd	0.03
Triangular fragment of copper cake	5-1938:22	HM1050a	0.55	0.02	nd	99.3	tr	nd	0.14	nd	nd	tr
Irregular copper cake fragment	5-1938:21	HM1051a	2.50	0.04	nd	95.6	0.60	0.79	0.09	nd	nd	0.38

Notes: tr = trace, nd = not detected

from further away. Ore deposits in the steep Nargvevi and Dogurashi stream valleys are hosted by lower and middle Jurassic hydrothermally altered, shared/brecciated and silicified rocks (Fig 6). Ore minerals found here are chalcopyrite ($CuFeS_2$), sphalerite ($(Zn,Fe)S$), galena (PbS) and marcasite (FeS_2). Secondary minerals are limonite, smithsonite and malachite. Wall-rock alteration includes sericitization, kaolinisation, silicification, carbonatization and pyritization. The ores are characterized by veinlet, massive and disseminated textures and also banded, colloform and breccia textures. The latter might indicate two-stage reactivation of hydrothermal fluids. Mineralization distribution is uneven, localized mainly in veins and mineralized zones (lens-shaped bodies) often forming pinch and swell structures as well.

Representative samples from mineralized zones, mineralization host rocks and slags have been subjected to atomic absorption spectrophotometry (AAS) analysis (Table 2). The results show clear correlation with historic data on copper, lead and zinc ores. This indicates the local origin of ore sources for copper smelting at the Dogurashi and other Lechkhumi sites. Further investigations into the provenance of metals and ores from this area will continue as will the search for prehistoric mines. This is a difficult task given the mountain topography, thick topsoil accumulation and dense vegetation cover, and no specific traces of early mining have yet been found but the search will continue while the ore geology is investigated. Besides, nearly all significant and accessible mineralization outcrops have been already explored by pre-Soviet and Soviet-period mine workings and some prehistoric mines may have been destroyed by these workings. Early mines have been noted in the alpine (less vegetated/more visible) areas of the northern and southern slopes of Great Caucasus at heights of around 2,500-3,000m (Chernykh 1992, 276).

Table 2: Metal assay results from ore mineral samples from the Dogurashi area analysed by atomic absorption spectrophotometry.

Reference/ID	Cu%	Zn%	Pb%	Au ppm	Ag ppm
Dog030/17	0.08	0.08	0.06	0.03	5
Dog037/18	0.01	0.01	0.01	<0.01	<1
Dog040/18(1)	2.88	0.23	0.04	0.01	5
Dog040/18(2)	0.03	0.21	0.03	0.10	7
Dog045/18(1)	1.79	11.6	8.35	0.50	111
Dog045/18(2)	2.12	10.1	9.8	0.02	141
Dog045/18(3)	0.45	4.34	2.8	0.07	34
Dog046/18(1)	<0.01	<0.01	<0.01	0.04	2
Dog046/18(2)	0.03	0.07	0.04	0.13	10
Dog048/17	0.02	0.01	0.01	0.02	<1
Dog051/17	0.02	0.01	0.01	0.02	<1
Dog060/18	<0.01	<0.01	<0.01	0.01	3
Dog061/18	<0.01	3.34	0.05	0.01	9
Dog062/18(1)	1.34	0.07	0.06	0.02	11
Dog062/18(2)	<0.01	<0.01	<0.01	0.03	<1

Recent and future work in Lechkhumi

Discussion of results

Ten prehistoric copper smelting sites have so far been located in the Lechkhumi area and another seven have been reported (see below). The group of three copper smelting sites, Dogurashi I, II, and III, are currently under detailed investigation and have reached different stages of study. Archaeological work has now been completed at Dogurashi I and radiocarbon dating results confirm it was operating between about the 13th and 9th century BC (Fig 9). There was clearly more than one – even intermittent – phase of smelting work here although only part of this survives; part of the working area, including any smelting furnace remains, has most likely been lost to subsequent erosion.

Detailed work (begun in September 2018) is underway at Dogurashi II and a large, possible roasting hearth was uncovered, together with demolished furnace debris. The work so far is very encouraging and shows Dogurashi II to be better preserved (therefore more difficult to see) than Dogurashi I. The geophysics results suggest that the working area may be more-or-less complete, including a smelting furnace the design of which is still unknown; its remains lie further away from the edge of the mountain terrace. Not all the magnetic anomalies were covered by the (unfinished) Area 1 so just before the 2018 season ended a new area (Area 2) to the NE was begun. This detailed excavation work will continue and finish in 2019. It is now clear that this industrial site was used for preparation (roasting) and smelting of copper ores during the transitional late Bronze to early Iron Age: the Colchian period. Many samples of the industrial waste (slag, rough crucibles, charcoal for dating etc) have been recovered and submitted for analysis; results are awaited.

Work at Dogurashi III has been restricted to magnetometry but this indicates the working area to be quite well preserved even though much of the adjacent slag dump has been removed by recent track-building work.

Study and analysis has begun on many copper ingots and cakes as well as finished copper alloy objects. Semi-quantitative XRF analysis has also begun on slag and other debris recovered during exploratory survey and archaeological investigation. Already we are starting to see the compositional markers for locally-made copper or copper alloy artefacts, as opposed to imports from other areas. The results presented here (Table 1) represent the first stage of this analytical investigation. More such work is underway and soon we hope to show what typifies local production of the Colchian transitional late Bronze Age/early Iron Age as opposed to imported contemporary material.

Prehistoric settlements that can be linked to the Colchian culture of the transitional late Bronze Age and early Iron Age, such as those at Tskheta and Dekhviri, have only recently begun to be recognized in the Lechkhumi region under later settlements and are being investigated archaeologically. Excavated finds include metalworking and other remains (ceramics, stone mould and casting debris), and chance finds have included copper ingot and cake fragments, slags (smithing and smelting) and copper alloy production waste material (Sakharova 1976; Sulava 2003; 2008; 2014).

This settlement material, as well as the hoards of metalwork found accidentally, all appears to be both contemporary with and complementary to the copper smelting industry which forms the central part of our project. This suggests that the establishment and continuation of these (and other?) settlements, the activities within them (particularly local metalworking craftsmanship), as well as the burial of votive offerings, were all linked to the local copper smelting industry as well as to local agriculture, all these activities contributing to the Colchian culture as well as being part of the yearly lifecycle of the local population.

Recent geological investigations have confirmed that raw material sources for copper production in the Dogurashi mountain area are linked to the base metal mineralization that developed here. Further provenance studies are planned using up-to-date analytical techniques as well as the continued geological exploration of the area and beyond.

Future work

Current interdisciplinary investigation of the late Bronze Age copper sites in the Dogurashi area, together with the location and study of similar sites, should enable us to assess the details and significance of the Lechkhumi region for copper production in the late Bronze Age and its place in the economy and culture of this part of ancient Colchis.

In addition to the ten prehistoric copper smelting sites so far located in the Lechkhumi area, another seven have been reported and will be a target for forthcoming exploratory survey. Two of these are near the left (east) bank of the Tskhenistskali River, towards Dogurashi, while the other five are in the mountain area to the west of the Tskhenistskali River. Other sites are claimed and will be investigated when more precise locations are known. The apparent clustering into two groups of prehistoric copper (and later iron) smelting sites so far located in Lechkhumi is likely to be a distribution map of archaeological findings rather than how copper smelting sites were actually distributed in the transitional late Bronze/early Iron Age. Too few sites have been located, and more exploratory work is needed together with archaeometallurgical investigation. The results of the present programme of investigation, as well as developing local contacts/knowledge will be used to improve the survey procedures.

The project to locate, excavate and study the previously unknown archaeometallurgical landscape of the Lechkhumi region will become a valuable contribution on a regional scale as well as providing a much more complete idea of the scale of prehistoric Colchian metallurgy across the wider region of (what is now) western Georgia (Adjara, Guria, Samegrelo and Svaneti).

Further survey, including the search for ancient mining traces and a study of possible ore sources, as well as excavation will continue as part of the on-going project and this should establish Lechkhumi as a regionally as well as nationally important centre of metallurgical production in the late Bronze Age. In addition to this, the rich variety of chance archaeological finds – mostly votive hoards from Lechkhumi or the surrounding area – can now be studied as part of this programme of work. The region is already well known for its characteristic Colchian metalwork and the present archaeometallugical work is aimed at understanding this better and putting it into its cultural context as well as understanding the technology and dating of metal production of the region and assessing its international contribution to the archaeometallurgy of copper in the transitional late Bronze Age/early Iron Age.

A parallel programme investigating contemporary metalwork from the Lechkhumi region will continue, plotting the find-spots (as far as is possible, given incomplete earlier records) of known hoards/votive deposits of metalwork. A variety of metalwork from twelve known sites will be studied but other possible sites are suspected.

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References

Abesadze T 2011, *Metal production in the Transcaucasus during the third millennium B.C.* [Reprinted and reissued with additional acknowledgements by the Georgian National Museum from the original publication of 1969] (Tbilisi) [in Georgian].

Academy of Sciences of the USSR 1958, *Natural Resources of Georgian SSR, Metallic Mineral Resources*, Vol 1 (Moscow) [in Russian].

[Anon] 1970, *Useful minerals map of GSSR, 1970: Explanatory note* (Tbilisi) [in Russian].

[Anon] 1974, *Geology of the USSR, Vol 10, Georgian SSR, mineral resources* (Moscow) [in Russian].

Bartholomeev G K 1907, Opitara ore deposits. Unpublished report 1298, Geological Funds of Georgian Agency on Mineral Resources, [in Russian]. See https://nam-geofund.archival-services.gov.ge/geofond/item_detailed/941.

Beridze M A 1983, *Geosynclinal volcanogenic-sedimentary lithogenesis on the example of Early Alpine formations of the Southern Slope of the Great Caucasus* (Tbilisi: Proceedings of Al Janelidze Institute of Geology of the Academy of Sciences of Georgian SSR) [in Russian].

Bezhanishvili N M 1933, Brief summary on the examination of the copper ore deposit in the vicinity of v. Opitara (Tsageri District). Unpublished report 1091, Geological Funds of Georgian Agency on Mineral Resources [in Russian]. See https://nam-geofund.archival-services.gov.ge/geofond/item_detailed/774.

Chernykh E N 1992, *Ancient metallurgy in the USSR: The early metal age* [trans S Wright] (Cambridge).

Craddock P 1995, *Early metal mining and production* (Edinburgh).

Erb-Satullo N, Gilmour B J J and Khakhutaishvili N 2014, 'Late Bronze and Early Iron Age copper smelting technologies in the South Caucasus: the view from ancient Colchis c.1500-600 BC', *Journal of Archaeological Science* 49, 147-159.

Geguchadze S, Gvineria S, Kalinina E and Beradze R 1976, Explanatory note for the *1:50 000 scale geological map of the Racha-Svaneti ore district*, P D Gamkrelidze and G A Tvalchrelidze (eds) (Tbilisi) [in Russian].

Ghambashidze D 1919, *The mineral resources of Georgia and Caucasia* (London).

Gilmour B, Cox M, Erb-Satullo N, Khakhutaishvili N and Pollard M forthcoming,'Ancient Colchis and the origins of iron: Interim results from recent field survey work in Guria, western Georgia', in N Sekunda (ed), *Wonders lost and found: papers in honour of Michael Vickers* (Oxford).

Gobejishvili G 1962,*The results of archaeological expedition of the southern slope of the middle of the [Greater] Caucasus in the Bronze Age in 1961', Summary of reports* (Tbilisi) [in Georgian].

Hauptmann A 2007, *The archaeometallurgy of copper: Evidence from Faynan, Jordan* (Berlin).

Ivanitski T V and Vezirishvili E K 1954, Geology and mineralization of the Rtskhmeluri ore field and Lentekhi mineralization (Kvemo Svaneti); Report for Institute of Geology and Mineralogy of the Georgian SSR Academy of Sciences. Unpublished report 8904, Geological Funds of Georgian Agency on Mineral Resources [in Russian]. See https://nam-geofund.archival-services.gov.ge/geofond/item_detailed/15666.

Janelidze T B 1965, Middle Jurassic volcanism of the Southern Slope of the Great Caucasus Geosyncline (the area in-between the Enguri-Tskhenistskali rivers). PhD thesis, Geological Institute of Georgian SSR Academy of Sciences, Tbilisi. Unpublished report 11640, Geological Funds of Georgian Agency on Mineral Resources [in Georgian]. See https://nam-geofund.archival-services.gov.ge/geofond/item_detailed/17289/0.

Jessen A A 1935, 'To the question of the oldest copper metallurgy in the Caucasus', *Izvestija Gosudarstvennoj Akademiiistoriimaterial'nojkul'tury* 120, 7-237 [in Russian].

Jones H L (trans) 1917, *The Geography of Strabo* Vol 1 (London, Loeb classical library).

Kalandadze A 1931, The communal department attitude on the issue of copper ore and other minerals deposits in villages Mekvena and Opitara. Unpublished report 1094, Geological Funds of Georgian Agency on Mineral Resources [in Russian]. See https://nam-geofund.archival-services.gov.ge/geofond/item_detailed/776.

Khakhutaishvili D 2009, *The manufacture of iron in ancient Colchis* (Oxford).

Mamardashvili G 2010, Public and family life in the population of Lechkhumi. Unpublished PhD thesis synopsis, Ivane Javakhishvili Tbilisi State University [in Georgian].

Nadiradze V R, Alibegashvili B A, Kakhadze E I and Otkhmezuri Z V 1973, *Formation conditions and distribution regularities of endogenous ore formations of Racha and Svaneti* (Tbilisi) [in Russian].

Rayfield D 2012, *Edge of Empires: A History of Georgia* (London).

Rezesidze N, Sulava N, Gilmour B, Beridze T and Chagelishvili R 2018, 'Prehistoric metallurgy in mountainous Colchis (Lechkhumi)', *Bulletin of the Georgian National Academy of Sciences* 12(1), 183-187.

Sagona A 2018, *The archaeology of the Caucasus from earliest settlements to the Iron Age* (Cambridge).

Sakharova L S 1966, The Late Bronze Culture of the Tskhenistskali River Gorge. Synopsis to MSc thesis, Ivane Javakhishvili Tbilisi State University [in Georgian].

Sakharova L 1976, *Bronze Hoards from Lechkhumi* (Tbilisi) [in Georgian].

Sulava N 2001a,'Letschchumi – eine bedeutendste frühe Metallurgie-Region in der Kolchis', in I Gambashidze, A Hauptmann, R Slotta and Ü Yalçin (eds), *GEORGIEN, Schätze aus dem Land des goldenen Vlies* (Bochum), 186-187.

Sulava N 2001b, 'Gussform', in I Gambashidze, A Hauptmann, R Slotta and Ü Yalçin (eds), *GEORGIEN, Schätze aus dem Land des goldenen Vlies* (Bochum), 375.

Sulava N 2003, 'On a small mould discovered in Lechkhumi', *Dziebani* 10, 31-37 [in Georgian].

Sulava N 2008,'On a small mould discovered in mountainous Colchis', in Ü Yalçin, H Özbal and A G Paşamehmetoğlu (eds), *Ancient mining in Turkey and the Eastern Mediterranean (AMITEM 2008)* (Ankara), 299-305.

Sulava N 2014, 'The prehistoric metallurgical exhibits of Tsageri Historical Museum', *Proceedings of the Tsageri History Museum* 1, 33-35 [in Georgian].

Sulava N, Aghapishvili P, Bakhradze I, Chagelishvili R, Kopaliani N, Koridze I, Mamardashvili G and Pataridze M 2012, *Varlam Makharoblidze Tsageri History Museum* (Tbilisi) [in Georgian and English].

Togonidze G 1933, Preliminary report on the works conducted in 1933 by the Opitara geological exploration party. Unpublished report 1093, Geological Funds of Georgian Agency on Mineral Resources [in Russian]. See https://nam-geofund.archival-services.gov.ge/geofond/item_detailed/775

Topuria P A 1938, About the slags from Racha and Lechkhumi: Report. Unpublished report 2087, Geological Funds of Georgian Agency on Mineral Resources [in Russian]. See https://nam-geofund.archival-services.gov.ge/geofond/item_detailed/1628/0.

Topuria P A 1938, 'About the slags from Racha and Lechkhumi: Report', *Geological Funds of Georgian Agency on Mineral Resources* 2087 [in Russian].

Tvalchrelidze GA 1961, *Endogenous metallogeny of Georgia* (Moscow) [in Russian].

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