Prehistoric Mining and Metallurgy in Uzbekistan: An Introduction

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Abstract

The earliest metal finds in Central Asia date the beginning of metalworking to the 6th/5th millennium BC. Often the Central Asian copper deposits and in particular those of Uzbekistan are mentioned as raw material sources, but without substantiating this with geochemical data. Also, systematic excavations in the mining areas were rarely carried out, and if, then usually at medieval sites that were already known from written sources. Prehistoric mining always played a minor role in the previous (Russian/Soviet) investigations, which is why only a rough description of the extent of Central Asian copper ore deposits and their significance in prehistoric times can be found in the literature. Therefore, only little information about the beginning of the exploitation of copper bearing deposits is available. On the other hand, the traces of prehistoric mining, especially in Uzbekistan, are often destroyed or covered by medieval and modern mining activities, for which reason the prehistoric exploitation of deposits can only be proven on basis of an analytical approach. Geochemical data are already available for the copper deposits of the Iranian highland or the Caucasus, but there exist practically no geochemical characterisation for the copper deposits of Central Asia. Therefore the primary aim of the project funded by the Deutsche Forschungsgemeinschaft (DFG) is, based on selective surveys and sampling of the ore deposits, the establishment of a data basis in order to investigate the potential of the Uzbek copper deposits in terms of their prehistoric exploitation. Another focus of the project is on the sampling and analysis of archaeological objects from Central Asia. Based on the conjunction of the chronological classification of the objects between the Chalcolithic and the Early Iron Age and the detailed geochemical characterisation of the ore deposits new knowledge about the prehistoric use of resources and their distribution over time is expected placing the importance of the copper ore deposits of Uzbekistan as suppliers of raw materials in a wider context.

Introduction

The beginning of metalworking in Central Asia dates back to the 6th/5th millennium BC as evidenced by single finds from the Anau IA layers of Kaushut, Mondjukly Depe, Chakmakly Depe and Anau Depe (Кузьмина 1966: 86; Terekhova 1981: 315–316). During the 4th/3rd millennium BC the number of typologically identifiable metal finds increased. The majority were smaller objects such as needles, awls and knives, while larger objects were only occasionally found, such as the axe from Yalangach Depe, the gouge from Kara Depe or the dagger from Dashly Depe (Кузьмина 1966: 86–88; Chernykh 1992: 29–31, Boroffka, Kurbanov 2015: 49–50). With the appearance of the large proto-urban centres at the foothills of the Kopet Dag during the 3rd millennium BC, an increase of metal processing can be

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observed. More than a thousand copper and bronze objects are known. The most intensively investigated objects are those from Sapalli, Dzharkutan, Dashly and Gonur Depe, which show typological parallels with metal artefacts from Afghanistan, Iran and the Indus valley (Chernykh 1992: 176; Kaniuth 2006: 158–160; Kraus 2016: 257; Kraus *et al.* in prep.). In this context, E. N. Chernykh (1992: 179) differentiates two production centres: Bactria, said to be a metallurgical centre with mining and smelting, and Margiana considered as a centre for just metal processing. At the beginning of the 2nd millennium BC the urban centres in the foothills of the Kopet Dag like Altyn Depe or Namazga Depe were abandoned and replaced by smaller settlements resulting in a massive migration eastwards towards Margiana and Bactria, where new settlement centres arose (Sarianidi 1981: 188–189; Kohl 1984: 135–137). Changes are also evident in the metal finds. The close connection to the Kopet Dag is still visible, but the influence of the Late Bronze Age Sapalli culture of Northern Bacteria is considerably stronger and the term Bactria-Margiana-Archaeological Complex (BMAC) became widely accepted.

Archaeometallurgical Research in Central Asia

Since the 1960s, a considerable amount of research on prehistoric Central Asian metal artefacts has been carried out by several scholars, and numerous metal analyses have been published[2]. According to the analyses mainly pure copper with natural admixtures of arsenic, antimony, silver and lead was processed (Черных 1962: 33; Кузьмина 1966: 86–88, Терехова 1974: 215; Рузанов 2013: 20; Kraus, Yagshymuradov 2015: 57) from the 6th until the end of the 4th millennium BC. With the beginning of the first half of the 3rd millennium BC copper alloys with arsenic, lead and tin were increasingly used, whereas copper-arsenic alloys were the dominating alloys while tin bronze only rarely appeared (Ruzanov 1999: 104; Salvatori *et al.* 2002: 87). Tin bronzes occur more frequently in Bactria during the second half of the 3rd millennium BC, while they are rarely found in the Margiana, where according to E. N. Chernykh (1992: 179–182) mainly pure copper and occasionally copper alloys containing arsenic and/or lead were used indicating an exploitation of polymetallic deposits. However, recent analyses of more than 850 metal artefacts from Gonur Depe in Margiana show that copper alloys with arsenic and/or lead represent more than 50 % of the total metal inventory, and that pure copper and tin bronze were also used (Kraus 2015: 202; 2016: 259). According to Ruzanov (1999: 104) the Sapalli culture (beginning of the 2nd millennium BC) mainly used copper-tin alloys, but also arsenic and lead bronzes as well as pure copper suggesting an import of the metal from southern Central Asia (Iran/Afghanistan) (Рузанов 1982: 10). More recent analyses of metal objects from the Sapalli culture showed similar results, with arsenic bronze preferably used, followed by tin bronze (Kaniuth 2006: 166). In the middle of the 2nd millennium BC the first evidence for the use of iron appeared, which, however, only during the 1st millennium BC became the dominant metal (Garner 2013: 10).

Concerning the provenance of the metals often Central Asian copper deposits and in particular, those of Uzbekistan were mentioned as raw material sources, but in most cases without substantiating this with geochemical data. Moreover, unlike in Europe, archaeological research on prehistoric mining in Central Asia is not based on a long "tradition". Investigations on prehistoric and early historical mining in Uzbekistan and adjacent regions

2 A comprehensive overview, although not complete, was recently provided by V. D. Ruzanov (Рузанов 2013).

were mainly conducted during the exploration activities of the Soviet Union in the first half of the 20th century, with the focus on mapping the ore deposits for possible industrial exploitation. Therefore, the old mines were recorded and described mainly by geologists and only occasionally by archaeologists (Массон 1930: 38). In addition to the exploration surveys, some archaeological soundings were also carried out, but most of them concentrated on medieval mining already known from written sources (Массон 1953: 12–15). However, systematic excavations of the sites were not conducted. Prehistoric mining was only of minor interest in the previous (Soviet/Russian) archaeological research. Therefore, only a rough description of the extent of Central Asian ore deposits and their significance in prehistory can be found in literature and consequently only little is known about the beginning of the exploitation of copper-bearing deposits.

As elsewhere, the beginnings of mining in Central Asia were Neolithic flint mines (Массон 1953: 7). It is assumed that deposits of native copper, such as Almalyk, Altyn Topkan or Kansaj were already exploited during the Chalcolithic or the Early Bronze Age (Исламов 1976: 35), although there is no archaeological evidence for mining activities from that period. The most indications for prehistoric mining were chance finds discovered during the geological expeditions and often regarded as evidence of prehistoric exploitation (Исламов 1976: 38). Often the exact circumstances of the discovery were not known in detail, so that the chronological and spatial classification is rather questionable. Only rarely have there been reports of artefacts that could be directly related to prehistoric mining, such as in Kani-Masur, where copper was mined in addition to lead/silver (Исламов 1976: 39; Sverchkov 2009: 144). On the other hand, the traces of prehistoric mining are often destroyed or covered by medieval and modern mining activities. V. D. Ruzanov already pointed out that a proof for the prehistoric exploitation of Central Asian copper ore deposits may only be possible by chemical analyses of ores and metal artefacts (Рузанов 1980: 61). Therefore, he tried to correlate different copper ore deposits in Uzbekistan and adjacent areas to individual archaeological cultures using chemical comparative studies on ores and metals (Рузанов 1982; Рузанов 2013). He emphasized the particular importance of the Bukantau-Tamdytau-Auminzatau-Complex in the Kyzylkum, the Chatkal-Kuraminsk-Complex in the Fergana-Ilak-Area and the Zirabulak-Karatyube-Zeravshan-Region as mining and metallurgical centres during the Bronze Age, but without discussing in detail the ore characteristics of the investigated deposits. The question of the origin of raw materials used for prehistoric metal production generally played a minor role in the Soviet Russian archaeological research and investigations concerning the geochemical characterisation of Central Asian copper ore deposits are largely absent and provenance analyses are therefore usually limited to mentioning potential copper ore deposits without, however, providing verifiable data. It was not until the middle of the 1990s when investigations concerning the origin of raw materials and their distribution started again in Central Asia and adjacent regions. These were predominantly concerned with the provenance of tin and gold (e.g. Parzinger, Boroffka 2003; Stöllner *et al.* 2010; Stöllner *et al.* 2011; Garner 2013; Stöllner, Samašev 2013), while the origin of Central Asian copper remains extremely hypothetical.

Aims and Methods of the Project

The state of research described above shows that only little is known about prehistoric copper mining in Central Asia. The project "PMU: Prehistoric Mining and Metallurgy in Uzbekistan" presented in this paper, funded by the Deutsche Forschungsgemeinschaft (DFG; project KR4876/1-1) is intended to fill these immense research gaps. Chemical analyses of metal artefacts provide an excellent classification of metal types, but are generally not sufficient for the provenance analysis of artefacts in relation to specific deposits. However, they are essential for all other methods with regard to the determination of origin, such as the lead isotope analysis.

A large amount of geochemical data is already available for the copper ore deposits of the Central Iranian highland (e.g. Pernicka *et al.* 2011) or the Caucasus (e.g. Meliksetyan, Pernicka 2010; Kunze *et al.* 2017), while there is practically no comparable analysis of the copper ore deposits in Uzbekistan. Therefore the primary aim of the project is, based on selective surveys and sampling of the ore deposits, the establishment of a data basis in order to investigate the potential of the Uzbek copper deposits in terms of their prehistoric exploitation. In this context, the focus is on early ore and metal extraction and the economic importance of the deposits for the cultures between the Chalcolithic and the Early Iron Age. This will shed light onto the technological development of early copper metallurgy in this region. Furthermore, recognizing the distribution patterns of prehistoric raw material resources in Uzbekistan will help to understand communication links between different societies and cultures based on the economic base in a wider context.

Mining Districts in Uzbekistan

The copper ore deposits investigated in the project are spread over eight mining districts (Fig. 1): the Kyzylkum Desert, the Nuratau Mountains, the Zirabulak/Ziyadin Mountains, the Kugitangtau Mountains, the Kyzyldarya Valley, the Fergana Valley as well as the Karamazar/Kuraminsk Mountains and the Chatkal Mountains.

The copper deposits of the Kyzylkum Desert are located in the mountain ranges of Bukantau, Sangruntau, Auminzatau, Tamdytau and Sultanuizdag. Several smelting sites and slag heaps indicate intensive mining activities at least since the Early Bronze Age in this region (Исламов 1976: 37; Sverchkov 2009: 155–156; Garner 2013: 127). Also known for a long time are the gold, silver and copper deposits of the Nuratau Mountains, for which an exploitation in the Middle Ages is regarded as assured. The discovery of stone tools and Bronze Age ceramics in the immediate vicinity also indicates prehistoric mining activities, especially on the northern slopes (Sverchkov 2009: 154–155). The Zirabulak/Ziyadin Mountains include the well-known Bronze Age tin mines of Karnab, Laps and Changaly, which have recently been investigated with regard to their prehistoric uses (see Parzinger, Boroffka 2003; Garner 2013). Not far therefrom are also copper deposits for which a predominantly medieval exploitation is assumed (Garner 2013: 247–248), but also a prehistoric use would be conceivable. The Kugitangtau Mountains are located on the border between Uzbekistan and Turkmenistan and contain mainly iron and polymetallic deposits. The two copper deposits of Chuyankan and Tillokan were discovered here in 1935, where numerous traces of mining were documented during first field surveys. A chemical analysis of some ores from Tillokan revealed lead, copper, iron and tin, among others (Рузанов, Буряков 1997: 175; Sverchkov

2009: 152). Therefore, the use of those ores in prehistory is quite conceivable, particularly since numerous slag finds nearby indicate a local smelting of the ores (Garner 2013: 249). The polymetallic deposits of the Kyzyldaya Valley are located in the southwestern foothills of the Hissar Mountains. Their exploitation dates back to the Middle Ages (Пругер 1986: 3), but a prehistoric use could not be excluded. Also, in the foothills around the Fergana Valley there are numerous, mainly polymetallic deposits (Исламов 1977: 51). The Naukat mining area is probably one of the most important copper deposits in this region. According to early analyses of its ores, it is assumed to be the copper supplier for the metal objects of the Bronze Age Kajrakkum (Литвинский *et al.* 1962: 172). According to O. I. Islamov, the occurrence of native copper could also be seen as indication of prehistoric mining (Исламов 1976: 35). The Karamazar/Kuraminsk Mountains in the Northeast of Uzbekistan are known for their rich gold and silver deposits, which were mainly exploited during the Middle Ages (Исламов 1977: 19). In addition to gold and silver also iron and copper were mined. The copper deposit of Almalyk is the largest deposit in Uzbekistan and still in operation. Worth mentioning are also the polymetallic deposits of Kansaj and Aktashkan, were finds of stone tools suggest prehistoric mining, but their traces are covered by medieval and modern mining (Sverchkov 2009: 144). Old mines were also discovered in the polymetallic deposits in the Chatkal Mountains, but are partly destroyed or covered up by the still ongoing mining (Sverchkov 2009: 145–146). However, mining archaeological and archaeometallurgical investigations on the origin, use and distribution of copper were carried out only very rarely or were not at all in all the mining areas mentioned.

Preliminary Results

In a first step the copper ore deposits of Uzbekistan needed to be surveyed for traces of prehistoric mining activities and sampled for archaeometallurgical investigations and geochemical analyses. Since not every occurrence of copper ore could be investigated on site, the sampling initially concentrated on the ores from the deposits stored in the magazine of the Geological Museum in Tashkent. Therefore, only those ore deposits were selected for sampling which were mentioned in literature as potential prehistoric raw material. Overall, around 140 samples were taken from nearly 50 sites spread over all the above-mentioned mining districts. Unfortunately, it was not possible to get representative sample sizes from all deposits of interest, but the analytical results will also help to get a first idea of their potential use in prehistory.

The scientific investigation of the ore samples is carried out at the Curt-Engelhorn-Centre for Archaeometry in Mannheim, Germany, and comprises the determination of their mineralogical composition using light and scanning electron microscopic methods and their chemical composition using wavelength dispersive X-ray fluorescence analysis (WD-XRF) as well as the determination of their lead isotope ratios using multi-collector mass spectrometry with inductively coupled plasma (MC-ICP-MS).

Based on the mineralogical investigations most ores contain typical oxidic as well as sulfidic ore minerals. The most frequent oxidic ore minerals are malachite (often associated with cuprite), azurite, brochantite and atacamite. Among the sulphide minerals, chalcopyrite together with pyrite and chalcocite dominate. But also, native copper appears in some deposits, as it is known from Dal'nee in the Karamazar/Kuraminsk Mountains and from Naukat in the Fergana Valley. Although the current state of chemical investigation is not yet complete, it is evident that some samples cannot be directly considered as potential ores due to their rather low copper content. But they characterise the respective deposits by their lead isotope ratios.

The diagram (Fig. 2) gives a first impression of the results of the lead isotope analysis. Comparing the lead isotope ratios with data from metal artefacts it becomes apparent, that due to their high contents of radiogenic lead the ores from the Kyzylkum were not used in prehistoric times. The analyses reveal that the beginning of the exploitation of the Central Asian deposits, in particular those of the Karamazar/Kuraminsk Mountains, can already be assumed in the Chalcolithic period, but also for the Middle and Late Bronze Age. Hence, this mining area seems to have been of high importance for a long time period, even though also other raw material resources have been exploited in the further course of the Bronze Age. And although it was not yet possible to identify individual deposits as raw material suppliers for specific sites, the potential of the Central Asian deposits has been known at least since the Middle Bronze Age and was of greater importance in the Late Bronze Age.

Conclusion and Perspective

The first results that were obtained in the project „PMU: Prehistoric Mining and Metallurgy in Uzbekistan", funded by the Deutsche Forschungsgemeinschaft (DFG), show that the Central Asian copper ore deposits were probably exploited during the Chalcolithic, but at latest since the beginning of the Bronze Age. In addition, it turned out that the database is not yet sufficient for a direct identification of copper deposits as raw material supplier for specific archaeological sites and further analyses are necessary. Therefore, it is planned to take and analyse additional samples from the deposits that have not yet been representatively sampled. This will allow a detailed characterisation of the copper ore deposits of Uzbekistan and will provide a suitable data basis for comparative studies. In this context, chemical and isotopic analyses will also be carried out on archaeological metal objects dating from the Chalcolithic to the Early Iron Age providing a more detailed understanding of the use of the deposits during the different periods.

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Bibliography

Boroffka, N. and Kurbanov, A.
2015 New Data on the Neolithic and Eneolithic of Central Asia: Dashly Depe (Turkmenistan). *Miras: Ylmy-Köpçülikleýin* Žurnal 1(57), 38–55.
Chernykh, E. N.
1992 *Ancient Metallurgy in the USSR: The Early Metal Age. New Studies in Archaeology*, Cambridge.

Garner, J.
2013 *Das Zinn der Bronzezeit in Mittelasien II: Die montanarchäologischen Forschungen an den Zinnlagerstätten. Archäologie in Iran und Turan* 12, Berlin.
Kaniuth, K.
2006 *Metallobjekte der Bronzezeit aus Nord-Baktrien. Archäologie in Iran und Turan* 6, Mainz.
Kohl, P. L.
1984 *Central Asia. Palaeolithic Beginnings to the Iron Age. Recherche sur les grandes Civilisations / Synthèse* 14, Paris.
Kraus, S.
2015 Untersuchungen an prähistorischen Metallfunden aus Gonur Depe, Turkmenistan. In: T. Gluhak, S. Greiff, K. Kraus, and M. Prange (eds.), *Archäometrie und Denkmalpflege 2015: Jahrestagung an der Johannes-Gutenberg-Universität Mainz, 25.-28. März 2015. Metalla, Sonderheft* 7 (Bochum), 201–203.
2016 Metallurgical Investigations in Gonur Depe, Turkmenistan. In: Н. А. Дубова, Е. В. Антонова, П. М. Кожин, М. Ф. Косарев, Р. Г. Мурадов, Р. М. Сатаев, and А. А. Тишкин, (eds.), Памяти Виктора Ивановича Сарианиди. Труды Маргианской археологической экспедиции 6 (Moscow), 257–264.
in print Archaeometallurgical Studies on BMAC Artefacts. In: B. Lyonnet and N. Dubova (eds.), *The World of the Oxus Civilization* (working title).
Kraus, S. and Yagshymuradov, G.
2015 XRF Analysis of a Chlacolithic Dagger from Dashly Depe (Turkmenistan). *Miras: Ylmy-Köpçülikleýin Žurnal* 1(57), 56–57.
Kraus, S., Schifer, T. and Pernicka, E.
in preparation The Archaeometallurgical Studies of the ROXIANA-Project (working title).
Kunze, R., Mödlinger, M. and Rödel, T.
2017 Felduntersuchungen zur frühen Kupfermetallurgie im Großen Kaukasus: ein Vorbericht. *Prähistorische Zeitschrift* 92(2), 289–303.
Meliksetyan, C. and Pernicka, E.
2010 Geochemical Characterisation of Armenian Early Bronze Age Metal Artefacts and Their Relation to Copper Ores. In: S. Hansen, A. Hauptmann, I. Motzenbäcker, E. Pernicka (eds.), *Von Maikop bis Trialeti. Gewinnung und Verbreitung von Metallen und Obsidian in Kaukasien im 4.-2. Jt. v. Chr. Beiträge des Internationalen Symposiums in Berlin vom 1.-3. Juni 2006. Kolloquien zur Vor- und Frühgeschichte* 13 (Bonn), 41–58.
Parzinger, H. and Boroffka, N.
2003 *Das Zinn der Bronzezeit in Mittelasien I. Die siedlungsarchäologischen Forschungen im Umfeld der Zinnlagerstätten. Archäologie in Iran und Turan* 5, Mainz.
Pernicka, E., Momenzadeh, M., Vatandoust, A., Adam, K., Böhme, M., Hezarkhani, Z., Nezafati, N., Schreiner, M. and Winterholler, B.
2011 Archaeometallurgical Research on the Western Central Iranian Plateau. In: A. Vatandoust, H. Parzinger & B. Helwing (eds.), *Early Mining and Metallurgy on the Western Central Iranian Plateau: The First Five Years of Work. Archäologie in Iran und Turan* 9 (Mainz), 633–687.
Ruzanov, V.
1999 Zum frühen Auftreten der Zinnbronze in Mittelasien. In: A. Hauptmann, E. Pernicka, T. Rehren & Ü. Yalçın (eds.), *The Beginnings of Metallurgy, Der Anschnitt, Beiheft* 9 (Bochum), 103–105.
Salvatori, S., Vidale, M., Guida, G. and Gigante, G.
2002 A Glimpse on Copper and Lead Metalworking at Altyn-Depe (Turkmenistan) in the 3rd Millennium BC. *Ancient Civilizations from Scythia to Siberia*, 8/1-2, 69–106.

Sarianidi, V. I.
1981 Margiana in the Bronze Age. In: P. L. Kohl (ed.), *The Bronze Age Civilization of Central Asia: Recent Soviet Discoveries* (Armonk, New York), 165–193.
Stöllner, T. and Samašev, Z.
2013 *Unbekanntes Kasachstan: Archäologie im Herzen Asiens I, II. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum vom 26. Januar bis zum 30. Juni 2013. Veröffentlichungen aus dem Deutschen Bergbau-Museum Bochum* 192, Bochum.
Stöllner, T., Ġambašiże, I., Hauptmann, A., Mindašvili, G., Gogočuri, G. and Steffens, G.
2010 Goldbergbau in Südostgeorgien – Neue Forschungen zum frühbronzezeitlichen Bergbau in Georgien. In: S. Hansen, A. Hauptmann, I. Motzenbäcker and E. Pernicka (eds.), *Von Maikop bis Trialeti – Gewinnung und Verbreitung von Metallen und Obsidian in Kaukasien im 4.-2.Jt. v. Chr.: Beiträge des Internationalen Symposiums in Berlin vom 1.-3. Juni 2006. Kolloqien zur Vor- und Frühgeschichte* 13 (Bonn), 103–138.
Stöllner, T., Samaschev, Z., Berdenov, S., Cierny, J., Doll, M., Garner, J., Gontscharov, A., Gorelik, A., Hauptmann, A., Herd, R., Kusch, G. A., Merz, V., Riese, T., Sikorski, B. and Zickgraf, B.
2011 Tin from Kazakhstan – Steppe Tin for the West?. In: Ü. Yalçın (ed.), *Anatolian Metal V. Der Anschnitt, Beiheft* 24 (Bochum), 231–251.
Sverchkov, L. M.
2009 A History of Research on Ancient Mining in Uzbekistan. *Archäologische Mitteilungen aus Iran und Turan* 41(2009), 141–164.
Terekhova, N. N.
1981 The History of Metalworking Production among the Ancient Agriculturalists of Southern Turkmenia. In: P. L. Kohl (ed.), *The Bronze Age Civilization of Central Asia: Recent Soviet Discoveries* (Armonk, New York), 313–324.
Исламов, О. И.
1976 Из истории геологических знаний в Средней Азии. Библиотека Всемирной Истории Геологических Наук 1, Ташкент.
1977 Из истории геологических знаний в Средней Азии: История геологических знаний в Средней Азии в феодальный период (*V в. н. э. – начало XIX в.).* Библиотека Всемирной Истории Геологических Наук 2, Ташкент.
Кузьмина, Е. Е.
1966 Металлические изделия энеолита и бронзового века в Средней Азии. Археология СССР свод археологических источников В4–9, Москва.
Литвинский, Б. А., Окладников, А. П. and Ранов, В. А.
1962 Древности Кайрак-Кумов (древнейшая история Северного Таджикистана). Труды Ин-та истории им. Ахмада Дониша 33, Душанбе.
Массон, М. Е.
1930 Археологические материалы к истории горного дела в Средней Азии, Бюллетень Среднеазиатского Районного Геологоразведочного Управления 2, Ташкент.
1953 К истории горного дела на территории Узбекистана, Ташкент.
Пругер, Е. Б.
1986 Горный промысел Южного Согда, Ташкент.
Рузанов, В. Д.
1980 К вопросу о металлообработке у племен чустской культуры. Советская археология 1980/4, 55–64.
1982 История древней металлургии и горного дела Узбекистана в эпоху бронзы и раннего железа. Исторические науки – 07.00.06 – археология, Автореферат диссертации на соискание ученой степени кандидата исторических наук, Москва.
2013 Металлообработка на юге Средней Азии в эпоху бронзы, Самарканд.

Рузанов В.Д. and Буряков Ю. Ф.
1997 Древние рудники и памятники металлургии в горах Кутитангтау. Узбекистон моддий маданияти тарихи 28, 175–178.
Терехова, Н. Н.
1974 Технология изготовления первых металлических орудий у древнейших земледельцев Южной Туркмении. Советская Археология 1974/1, 69–78.
Черных, Е. Н.
1962 Некоторые результаты изучения металла анауской культуры. Краткие Сообщения о Докладах и Полевых Исследованиях Института Археологии 91, 30–38.

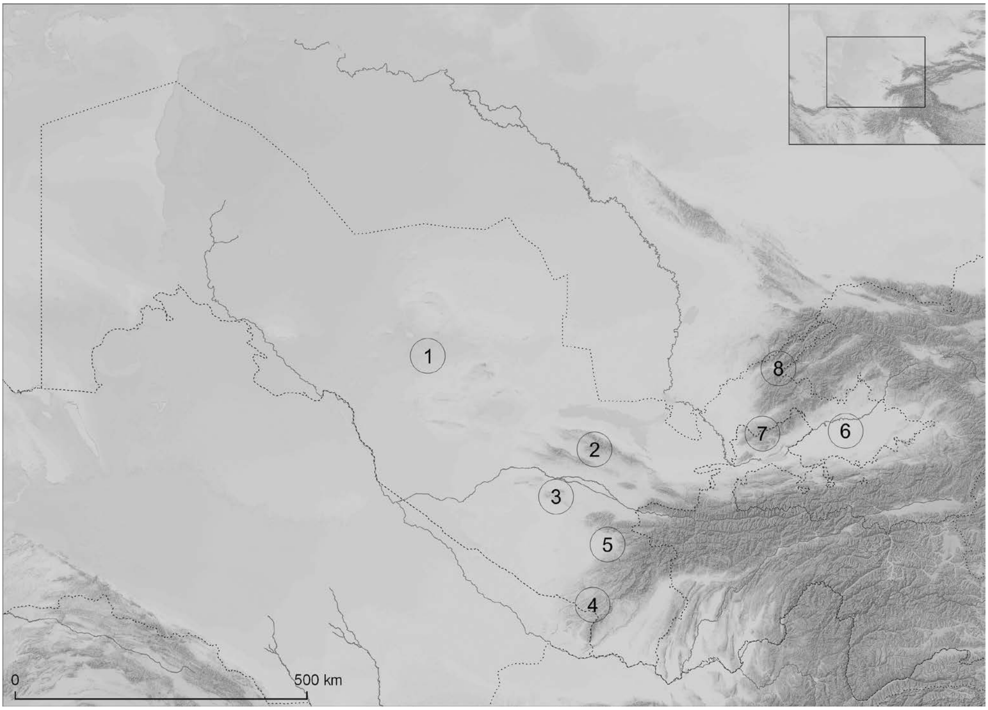

Fig. 1: Mining Districts in Uzbekistan investigated within the project: (1) Kyzylkum Desert, (2) Nuratau Mountains, (3) Zirabulak/Ziyadin Mountains, (4) Kugitangtau Mountains, (5) Kyzyldarya Valley, (6) Fergana Valley (7) Karamazar/Kuraminsk Mountains (8) Chatkal Mountains (Map: S. Kraus)

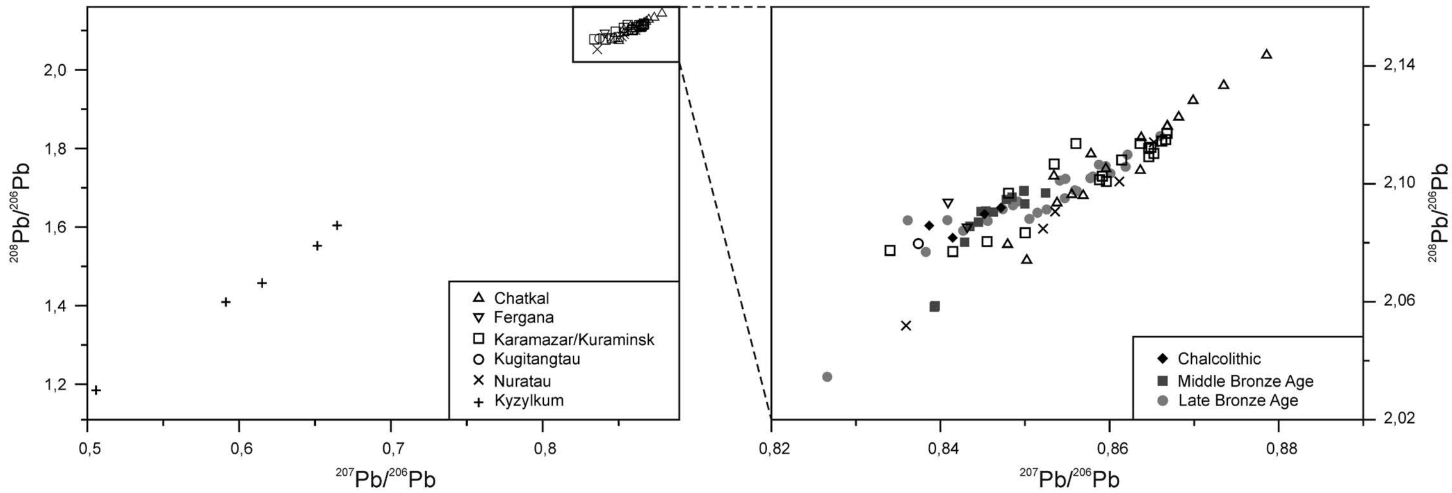

Fig. 2: Lead isotope diagram comparing copper ores and metal artefacts from different time periods. The standard deviation (2σ) is smaller than the symbols (artefact data provided by Kraus 2016: 262; Kraus in prep.; Kraus *et al.* in prep.)