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TIN IN SOUTHEASTERN EUROPE ?

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Apart from Cornwall, the only indisputable source of tin in the prehistoric Europe, some new potential sources in Southeastern Europe (on the mountains Bukulja and Cer in western Serbia), should be considered. The fortunate coincidence, that the deposits of copper and tin ore were found close to each other, very likely played the crucial role in the production of full-fledged bronze towards the end of the Vučedol culture (phase C).

Key words: Tin, Bukulja, Vučedol Culture

After the publishing of Colin Renfrew's well-known study on the autonomous development of metallurgy in south-east Europe, in 1969, the prehistorical archaeology of Southeastern Europe took on a much more peaceful and uniform course. On the basis of research on early mining activities, carried out by Borislav Jovanović (1975) and Evgenij Chernych (1975), and numerous findings from the Bronze Age period, we have been able to follow the continuity of metallurgical developments - starting with the first metal finds pertaining to the Starčevo culture (Chapman and Tylecote, 1983), through the Vinča, Gumelnita, and Salcuta cultures (Jovanović, 1971), to the Baden and Vučedol metallurgical production (Durman, 1983).

In the development of copper metallurgy we can distinguish three major steps (and several intermediate stages). These are: cold hammering, the "lost wax" casting technique and the metallurgy of arsenic bronze. In other words, we can observe the development from the initial phase when pure copper was gathered in its natural form, to the stage of digging oxide and carbonate copper (which implies the exploitation of the oxide type of ore); and finally the transition to the sulfide ore, i.e. tennantite and tetrahedrite, from which arsenic bronze, or, as in the case of the Vučedol culture, antimony bronze, is produced (Durman, 1983).

Arsenic bronze was, without doubt, introduced to this part of Europe by the Baden culture. This was confirmed by some recent analyses of the material from the Vučedol site at which a triangualar dagger, containing 1.5% of arsenic (Težak-Gregl, 1988), and a smaller dagger, with 5.496% of arsenic (in grave no. 3) were discovered in the Baden layer in 1984.[1] It seems, however, that at the beginning of the early Bronze Age this metallurgical practice must have been abruptly interrupted. Namely, although numerous sources of copper ore existed in that area, the presence of the other important component - tin - cannot be explained.

Most studies treating the subject simply evade this problem. Since no data were available on the presence of tin in the south-east of Europe, more and more authors started to suggest the existence of remote sources as a solution to this problem -

[1] Neutron activation analysis by I. Orlić, Rudjer Bošković Institute, Zagreb.

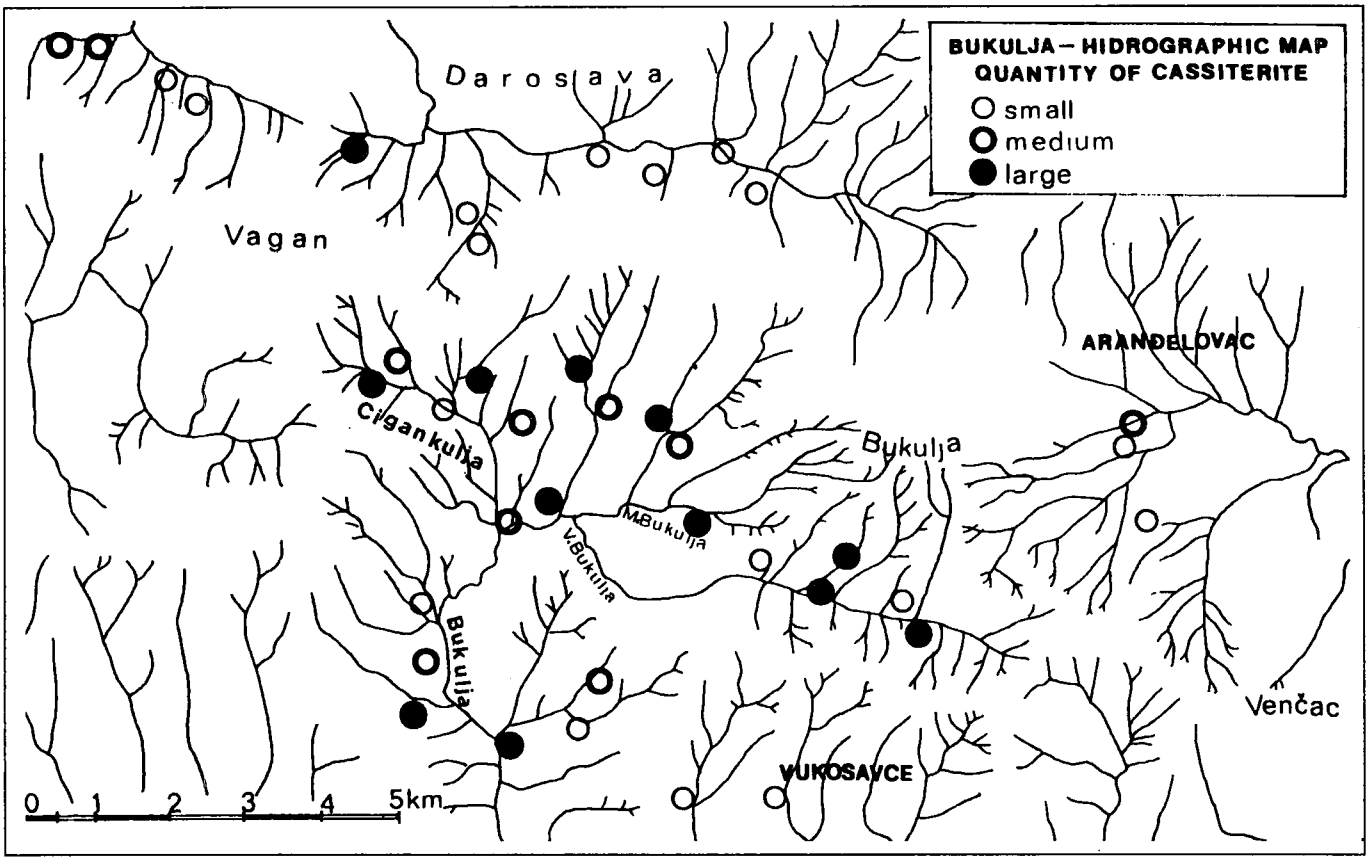

Fig. 1 Bukulja Mountain (acc. to S. Maksimović, 1961: 23)

primarily the sources in the mountains of Northern Bohemia and Southern Saxony (Erzgebirge). The range of disputes that followed can be illustrated by two extreme positions represented by Dayton (1971), on the one hand, and Muhly and Wertime (1973) on the other.

In his article on the problem of tin in the Ancient World metallurgy Dayton says "that the streams of northern Bohemia may have carried alluvial tin, but what is more important, here as in Cornwall, stannite, and mixed ores of copper and tin occur together" (1971: 57). This assumption was again opposed by Muhly who writes: "The tin deposits of the Erzgebirge were of a hard rock type, resulting not in the formation of alluvial or placer cassiterite but in seams of cassiterite burried in granite rock deep beneath the surface of the earth and thus not accessible to a Bronze Age prospector", and claims that "(....) the history of Saxo-Bohemian tin was a history of hard rock mining (....) to go back no earlier than the twelfth century A.C."(1985: 290).

So how can we explain the origin of tin in the bronze of South-eastern Europe? The first data about the existing, and several potential deposits of tin in the Central Balkans, were presented to me by Dr. Antonije Antonović, a geologist, while in the geological literature the problem was discussed by S. Maksimović (1961), K. Mihajlović (1978) and F. Tućan (1957).

As J. Muhly says: "Most important of all is the absolute geological principle that tin is to be found only in association with granite rock" (1985: 277). Dr. Antonović suggested the mountain of Bukulja in Western Serbia as a possible source, and K. Mihajlović (1978: 624) wrote that "Alluvial cassiterite deposit Cigankulja spreads along the southern slope of Vagan Hill, 8-12 km west from the nearest town Aranđelovac (Šumadija District)", and he goes on to say: "Cassiterite is the most dominant among the concentrated minerals (....) The grains of cassiterite are mostly irregular in shape and size. They also vary in color ranging from light brown to nearly dark. (....) The content of tin in cassiterite appears to be approximately between 60 and 78% ."

Alluvial deposits are shallow, barely three to four meters, and one cubic meter of the deposit yields an average of 449 grams of cassiterite. It is estimated that the alluvial deposits of the Cigankulja stream contain 250 tons of pure tin, and the preparations for exploitation are already under way (Mihajlović, 1978: 623). If we consider that, according to the available analyses, the average composition of bronze contains 10% of tin, such quantity would suffice for 2500 tons of bronze (2.5 million kilos of bronze!). The results of a recent study show that deposits of tin also spread into the neighbouring area.

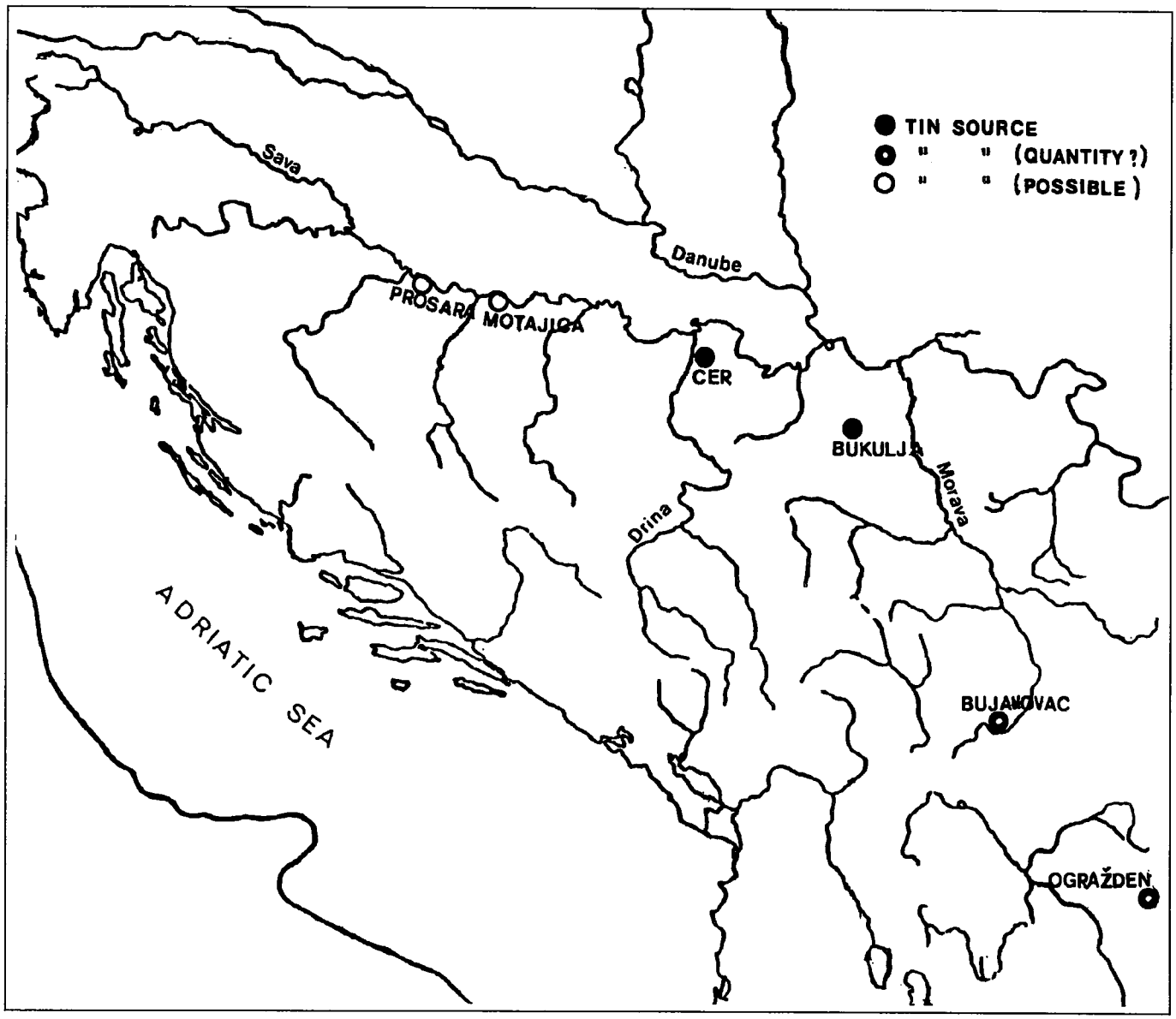

Fig. 2 Existing and possible sources of tin in Bosnia, Serbia and Macedonia

The question whether traces of some older activity can be found in the Cigankulja stream naturally crops up. Unfortunately, however, this question is impossible to answer without more extensive expertise, since, according to the personal account of K. Mihajlović, after a single storm that occurred in 1968, the water erased all traces of long-term digging.[2]

To cite Muhly again: "Most important of all is the absolute geological principle that without granite there is no possibility of tin ever having been present (....) Of greater relevance is the revival of the concept of metallurgy in provinces and the formation of metallic belts - copper belts, lead zinc belts and tin tungsten belts - extending over wide areas, as part of on-going reserach on plate tectonics and theories of continental drift." (1985: 277)

A. Antonović also points to the same fact when he emphasizes the very similar geological composition of the mountains Bukulja and Cer in Serbia and Motajica and Prosara in Bosnia.[3] If we conceive the above as a possible "mine chain", then it would run parallely to the Sava river, as the outmost soutehern boundary of the Pannonian valley over 300 km in length.

[2] In personal communication at the International Symposium on Ancient Mining and Metallurgy in Southeastern Europe, D. Milanovac, May 1990, Prof. B. Rothenberg also supported such claims, i.e. that it would be difficult to determine past exploitation of tin in alluvial deposits in beds of still existing streams.

[3] The mountains Motajica and Prosara (in Northern Bosnia) have not as yet been seriously researched. However, prof. J. Pamić from the Geological Institute in Zagreb, expert for this region, confirms the assumption of A. Antonović that Cer and Bukulja belong to the same chain and the same rock type.

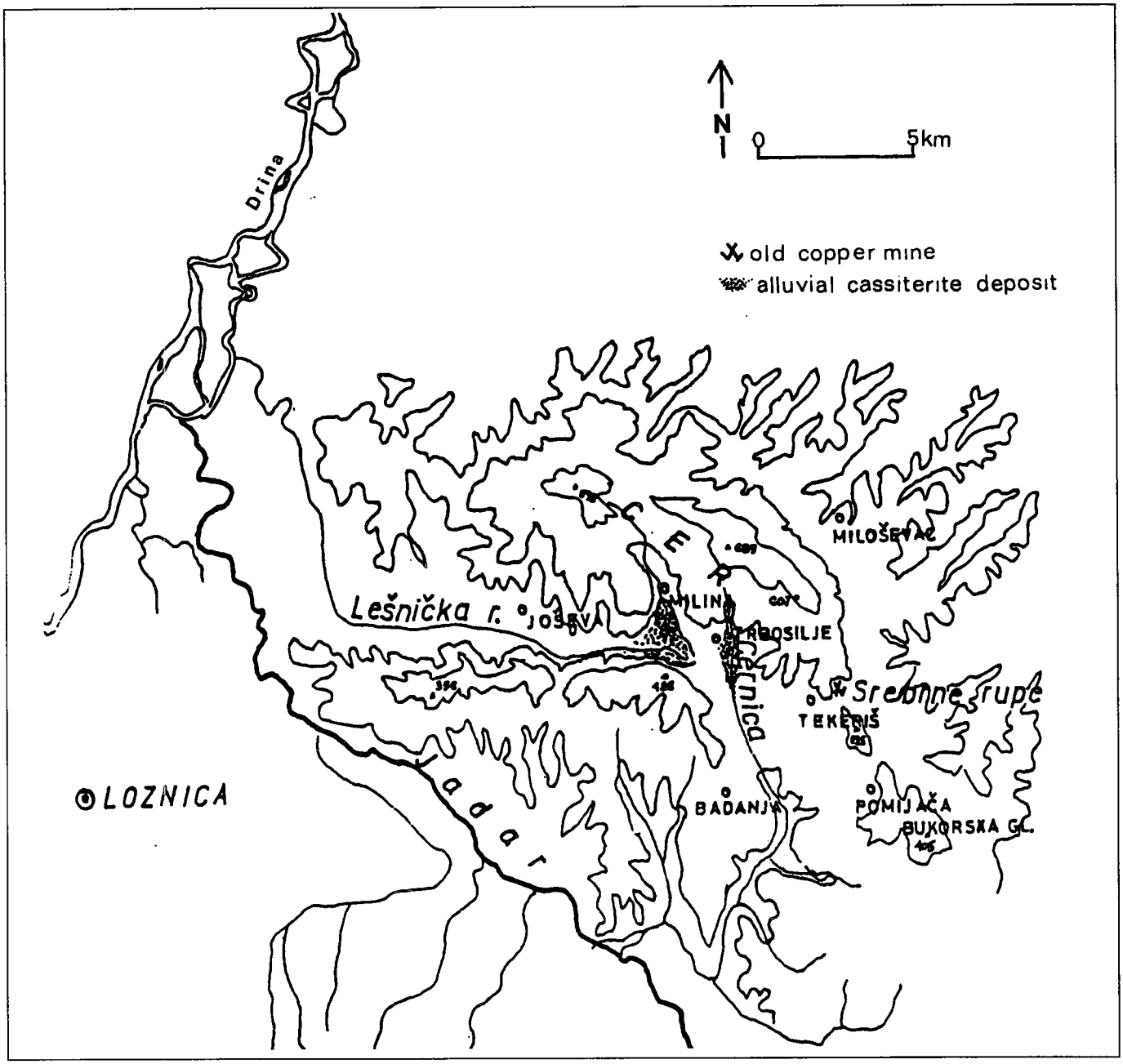

Fig. 3 Cer Mountain (acc. to M. Panić, 1990)

According to the most recent geological research still in progress, at the foot of the Cer mountain (Western Serbia) in the alluvial deposits of the Lešnica and Cernica river valleys, tin is found in quantities of 300-500 grams/m^3. The total quantity has not yet been determined, although present evaluation rates it far above those found at Bukulja (Panić, 1991).

Finely grained alluvial cassiterite was also discovered at the site of the Bujanovac granite massive in the upper regions of the southern Morava river[4] and in Macedonia, east of Strumica, where it originates from the granite rocks of the Ograždden mountain (Tućan, 1957: 209; samples and data obtained by Ljudevit Barić). The potential quantities have not been estimated for any of the above quoted sites.

This means that, for the time being, we can speak with certainty only about findings of tin on the mountain of Bukulja, primarily the alluvial deposits in the Cigankulja creek and the Cer mountain with the rivers Lešnica and Cernica.

The finding of cassiterite placers at Bukulja can be related to the sources of copper ore on the Rudnik mountain, about 20 kilometers to the South, i.e. only a day's walk away.

[4] Date obtained by A. Antonović.

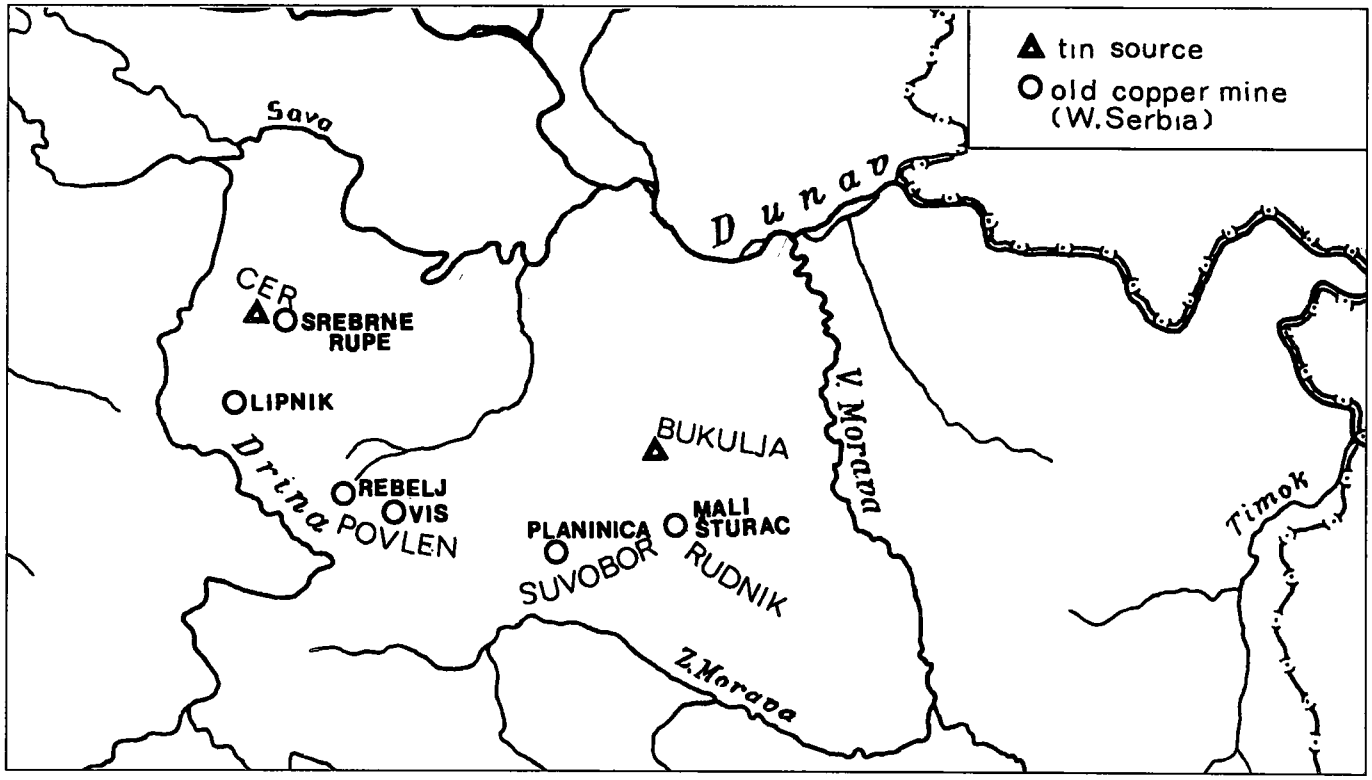

Fig. 4 Tin and copper sources in W. Serbia

B. Jovanović (1988) excavated sites along the line that can be drawn between Prljuša and Mali Šturac on the Rudnik mountain and determined that numerous mining activities and remains of artefacts (stone hammers and ceramics) were connected with copper exploitation, as well as the fact that they belonged to the late Copper Age or early Bronze Age. Copper is present in the form of cubanite and chalcopyrite (Krajnović and Janković, 1995: 26), which marks the transition to a new type of sulfur ore in which copper and iron are found together.

An even more favorable situation can be found at neighboring tin and copper placers on the Cer mountain, with the old, as yet not fully researched copper mining activities, located at the sites Srebrne Rupe and Kram in the Tekeriš village, only a few kilometers away from the alluvial tin deposits of the Cernica river (Panić, 1991). Numerous archaeological Copper age and Bronze Age finds and sites of this region (Vasiljević and Trbuhović, 1985) speak in favor of intense human activity in the early metallurgic periods of European prehistory. Such a fortunate coincidence of copper and tin deposits located in the same area, could provide the possibility for those early metallurgists to experiment with both metals and thus open up possibilities for the creation of the "strategic nucleus" which introduced this part of Europe into a fully autonomous Bronze Age.
Concerning the possibility of smelting the ore into pure tin J. A. Charles says (1975: 22): "Tin is difficult to refine and the purity of smelted tin will depend directly on the purity of cassiterite (....) The remaining possibility is that the tin was added to the copper from a mineral form, without prior reduction to tin, even in conditions of itinerant founding."

According to the Middle European chronology, the late Vučedol culture was, at the very end of the aenolithic period (Durman, 1989), the only culture that filled the span from the northern Bohemian

	Cu	Fe	Zn	As	Sr	Aq	Sn	Pb	Sb	Mo	In
1	94.243	2.199	0.475	0.472	-	0.039	0.048	2.4	-	0.027	0.007
2	97.569	0.848	0.264	-	-	0.045	0.024	1.122	0.125		-
3	89.074	9.529	0.23	0.183	0.304	0.044	0.039	0.538	-	-	-
4	88.501	3.433	0.282	-	0.068	-	7.23	0.281	0.203	-	-

Table 1: (1) remainder of smelting; (2) awl; (3) stick pointed at both ends (4x4 mm, similar to an ingot) ; (4) thin plate

mountains to western Serbia, and covered two regions known for the presence of tin ore. However, on the basis of the metal findings and present state of research, it can be deduced that in spite of the impressive metallurgic activity (Durman, 1988), this culture never managed to produce real, full-fledged bronze.

However, it has to be emphasized that in the late Vučedol culture the beginning of a new process was recorded, a transition from one type of sulfur ore (tennantite and tetrahedrite) to a new type - chalcopyrite (copper and iron), as registered in Rudnik - which most likely triggered the need for the first true alloy created by intentional addition of tin.

In an older layer of the Vučedol culture (B^2) at the site Vinkovci-Hotel three copper artifacts were found, and yet another one proceeds from a later, mixed layer. Their composition is as follows:

The quantity of iron varies from 0.848% to 9.529%, indicating that the metallurgists were still not able to stabilize the process of purification and separation of iron.

It happened sometimes that, due to a fortunate coincidence, among its nonmetallic components the ore contained flux, a substance promoting fusing.

"The iron content of the copper depended on the level of carbon addition. In the temperature range of 1150-1200 C copper is capable of dissolving about 4% Fe. Iron which is reduced and which is in excess of that saturation value will collect and float on the top of the copper. "(Rostoker and Sadowski, 1980: 40)

For a chalcopyrite ore concentrate, flux edition of silica (quartz) and tricalcium phosphate (most probably as bone ash) allowed slags which were molten and very fluid at about 1130 . "Wood ash - rich in lime, potash and silica - will also serve as a flux with pouring temperatures (....) The proportion of carbon is critical. Too little carbon results in low copper recovery and too much carbon brings on a high iron content in the copper and in further excess generates segregated iron which is not very separable from the copper." (Rostoker and Sadowski: 1980: 42).

It can be stated, therefore, that the use of tuyčres became justified only with the chalcopyrite ores, and it was recorded for the first time in the late Vučedol layer in Vinkovci, as well as numerous other late Vučedol sites (Zecovi, Debelo Brdo, Varvara in Bosnia and Ljubljansko Barje in Slovenia), along with double molds (Durman, 1983).

However, the successful separation of copper from iron in chalcopyrites still resulted in soft copper, so that for the production of alloy it was necessary to introduce another additive to replace the poisonous arsenic (tennantite, tetrahedrite) which could render it the hardness that had been achieved by the addition of arsenic or antimony.

An object (T. I, 4) from the Vinkovci layer, where the late Vučedol phase coincides with the Vinkovci-Somogyvar culture, clearly demonstrates the work of an unskilled smelter, not being able to separate iron but already adding tin to his alloy. The Vinkovci-Somogyvar culture marks the beginning of the Bronze age in the Pannonian valley.

In his article on the results of the excavation at Sitagroi, C. Renfrew (1971: 276) rightfully associated the layer Va (containing the "Burnt House") with the Vučedol culture, or, as it could be more precisely established, its late C phase. Two objects found in that layer (No. 28 - awl or pin and No. 32 - irregular shape) contain 3.4% and 8.1% of tin, respectively (Mc. Geehan-Liritzis and Gale, 1988: 202).

The most important Vučedol site in western Serbia - Đurđevačka Glavica - is located some thirty kilometers from the mountains Bukulja (tin) and Rudnik (copper), not far from the river Morava, the traditional way to Greece. Sitagroi is located about 500 kilometers to the south from Bukulja.

The connection of the Vučedol culture with the Aegean area, both to the east and to the west from Chalcidice (Sitagroi), can be deduced on the basis of the hoard of Petralona which, by its inventory and the composition of metal, fully corresponds to the Vučedol hoards as well as the finds of double molds (Durman, 1983). This analogy suggests the traditional way to the South along the river Morava and the Vardar valley (Axios) towards Petralona. In the earlier prehistory, however, the connection of the Pannonian valley with Aegea across eastern Macedonia by the Strumica valley (Strimon) in direction of Sitagroi, which had been known from the time of Vinča culture, was far more important.

Still, the biggest surprise of Sitagroi are the two finds of tin bronze from layer IV, because, according to Renfrew (1971: 276) and Sherratt (1986, fig. 13, 3a), this layer contains the elements of the Baden culture and is, supposedly, contemporary to it, and they contain 5.9% and 3.2% of tin, respectively (Mc Geehan-Liritzis and Gale, 1988: 202). Along with the tin they also contain a substantial quantity of lead (4 and 2.1%), comparable to the three Vučedol samples (B2) in Vinkovci (2.4%; 1.12% and 0.54%).

As Muhly points out (1991: 366), the finds of full-fledged bronze from Sitagroi IV are perhaps the earliest in the ancient world.

The Vučedol culture is, at the site of Đurđevačka Glavica, preceded by the Baden culture as - it deserves to be mentioned - its southmost site. At the time of the Baden culture true bronze was not yet known in the Pannonian valley, so that, apart from the deposits of tin at Bukulja and Cer, the sources of tin for the layer IV should perhaps be sought closer to Sitagroi. According to the date provided by a geologist F. Tućan (1957: 209), one of the possible sources could be the Ogražden mountain, hardly one hundred kilometers away from Sitagroi,

upstream the Strumica (Strimon) river. He also mentions the finds of cassiterite north of the town of Strumica (more precisely in the sand of the Kriva Topola creek in the vicinity of Ilovica), but more substantial geological research at the Ogražden Mountain is required.

It is possible that it was precisely the experience with tin gained at Sitagroi IV that launched the exploitation of tin in the late Vučedol culture in the peripheral Pannonian zone, so that it consequently, in layer V, established an emporium of a kind for its connection, via Limnos, with Asia Minor (Troy II etc.)

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SAŽETAK

KOSITAR U JUGOISTOČNOJ EUROPI?

Ključne riječi: kositar, Bukulja, vučedolska kultura

Cornwallu, jedinome nedvojbenom izvoru kositra u prapovijesti Europe, mogu se dodati i potencijalni novi na jugoistoku Europe - na planinama Bukulji i Ceru (zapadna Srbija). Sretna okolnost da su se ležišta bakra i kositra (kasiterita) našla u blizini vrlo je vjerojatno iskorištena na samom kraju vučedolske kulture za dobivanje prave bronce. To potvrđuje i bronačani amorfni nalaz iz Vinkovaca (Hotel) iz sloja u kojem se miješa kasna vučedolska (faza C) i rana Vinkovci-Somogyvar kultura(T. 1,4). U nekoj vrsti vučedolskoga emporija u sjeverozapadnoj Grčkoj - Sitagroi (sloj Va) - nađena su dva brončana predmeta koja svjedoče o proboju vučedolske metalurgije s novim metalom do Egejskoga mora.