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# Glacial Fluctuations and Exploitation of Copper Resources in High Mountain During the Late Neolithic and Bronze Age in the French Alps (2500-1500 BC)

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## The Beginnings of Metallurgy in the South of France

During the late Neolithic – at the limit of the 4<sup>th</sup> and 3<sup>rd</sup> millennia BC – copper exploitation is growing in the southern of France (Fig. 1). On the southern edge of Massif Central southern edge of and the Pyrenees, the mining district and metallurgical processes develop extractive metallurgy of low-productivity metal. The diffusion of production is then transferred to local networks. The development of this metallurgy first contribution is mainly to areas of small and medium mountains. This model, which could be called "Neolithic system" is completed in the second half of the 3<sup>rd</sup> millennium, between the 25<sup>th</sup> and 24<sup>th</sup> century BC (Fig. 2), with the abandonment of mining operations, a modification of the terms of metal consumption and supply networks.

## Mine and Metallurgy in Saint-Véran Area (Hautes-Alpes)

In the French Alps, we observe, from the 24<sup>th</sup> century BC onwards, the expansion of copper exploitation of resources located in high mountain context. Around 2350 BC began the exploitation of bornite in Saint-Véran (Hautes-Alpes).

The mining and metallurgical complex of Saint-Véran is situated in Haut-Queyras (Hautes-Alpes). Here, as at Cabrières, separate sites devoted to ore extraction and metallurgical activities were concentrated in the same small area (Fig. 1). The numerous research studies

conducted by Pierre Rostan and his team in the heart of the complex have provided a considerable amount of information concerning the mining activities of Saint-Véran, and the Pinilière rock-shelter (Rostan et al., 2002). Hélène Barge's study of the metallurgical workshop of La Cabane des Clausis (Barge, 1997) has greatly added to our knowledge of the context of protohistoric metal production in south eastern France (Barge et al., 1998).

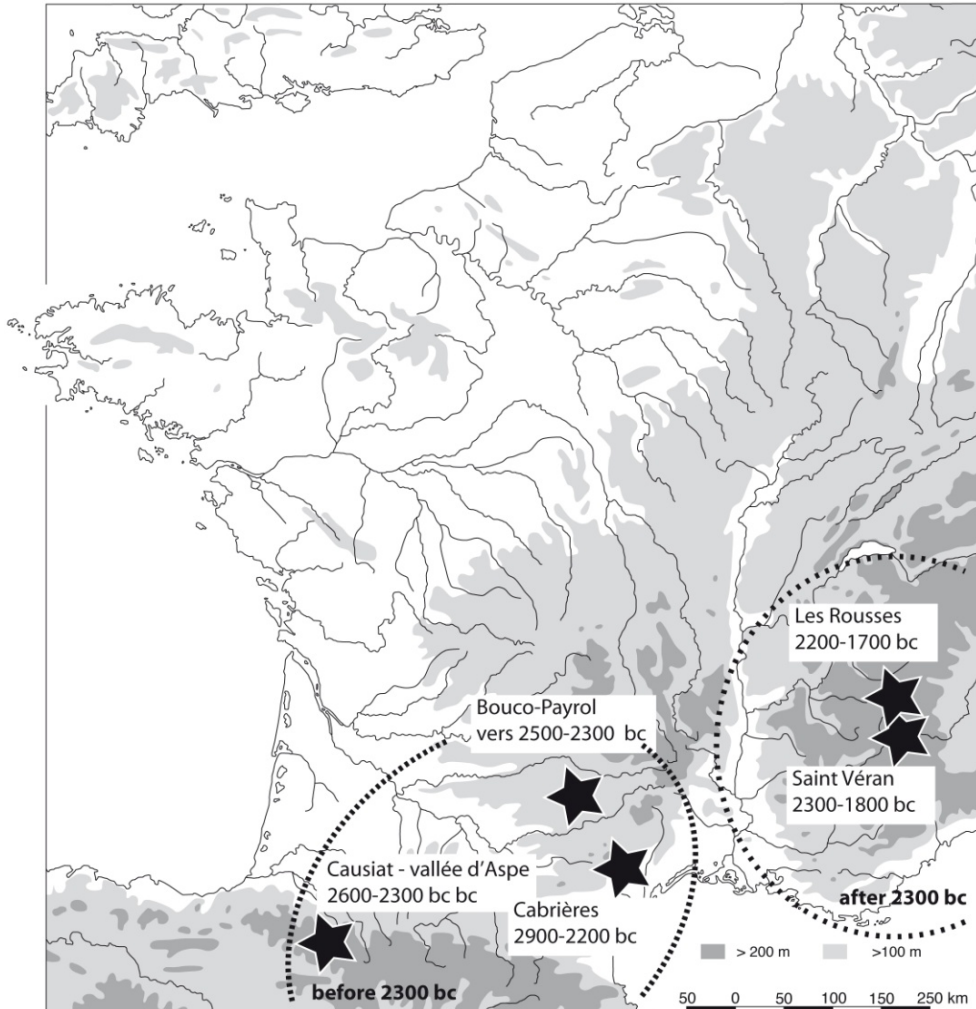


Fig. 1: Late neolithic and early Bronze Age mining complexes.

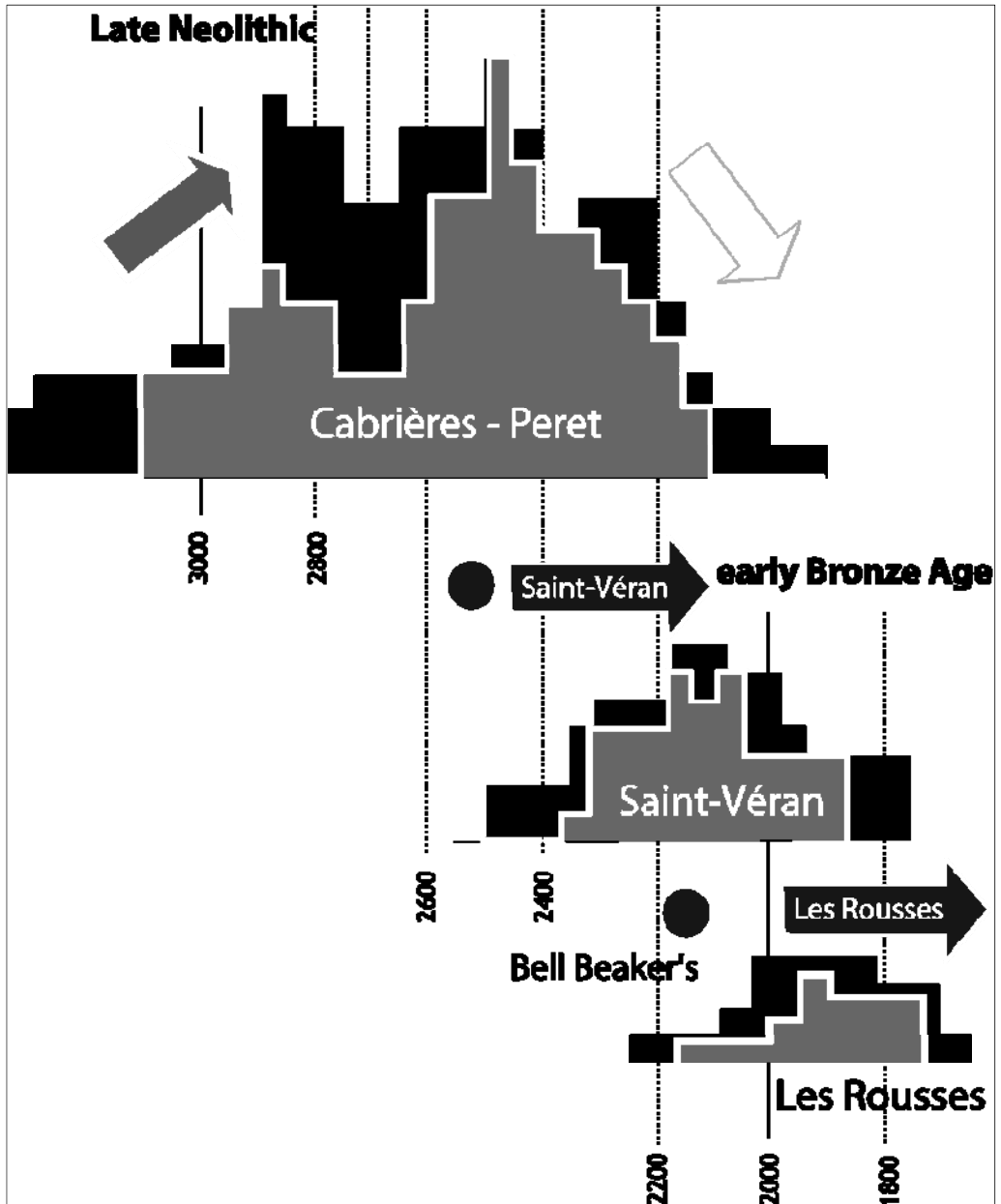


Fig. 2: Absolute chronology of mining complexes Chalcolithic and Early Bronze Age: Cabrières (Hérault), Saint-Véran (Hautes-Alpes) and Les Rousses (Isère).

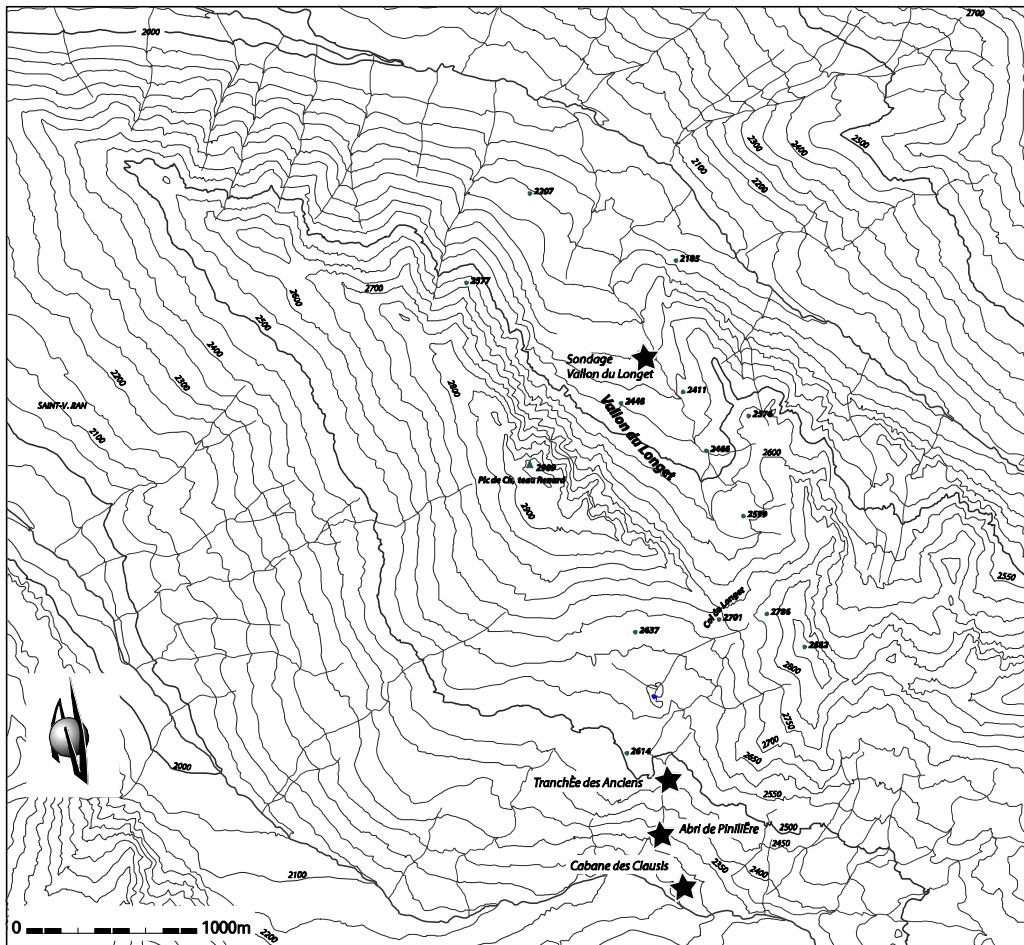


Fig. 3: Copper resources exploitation in the area of Saint-Veran and Molines en Queyras (Hautes-Alpes), DAO A. Burens UMR 5602 Geode.

The trench pillar - known as the "Tranchée des Anciens", delivered nearly 400 m<sup>3</sup> of ore processed in workshops situated at an altitude above 2300 m (Fig. 3). Numerous dates have been obtained for the Saint-Véran mining works and the metallurgical zone of La Cabane des Clausis; we shall here only discuss those relating to the period under consideration (Barge et al., 1998). Other factors suggest that attempts may have been made in the final phase of the Bronze Age and the beginning of the Iron Age to re-exploit the site. It seems that it was not possible to reach the submerged deposits with the mining techniques available. The dates

obtained in different horizons on the La Cabane des Clausis site cover the period extending from the second half of the twenty sixth century BC to the eighteenth century BC (Fig. 2), thus covering the whole of the Bell Beaker phase, i.e. the extreme end of the Neolithic, and the Early Bronze Age. If we add the dates and their range of probability per half century together, we find that the period between the twentieth and the twenty-fourth centuries BC is preponderant. From a cultural point of view, objects do not help clarify our perception of the situation.

### *Mining Exploitation of «The Trench Pillar»*

The deposits at Saint-Véran are of a sedimentary exhalative type created by submarine hydrothermal sources. They are now tilted vertically, have a pseudo veined appearance resulting from Alpine tectonics, and are distributed over a steep slope between 2250 and 2600 metres high. Two roughly parallel veins can be seen on the surface about twenty metres from each other. The quartzites which accompany the mineralisations are spread along a distance of about 1 km up to the Longet valley. These two veins were exploited in ancient times. The west vein is about 490 m long for a drop of 40 metres; the east vein is 650 m long for a drop of over 70 metres. The production has been estimated at about 2,000 tons of ore (Rostan, et al. 2002).

### *The Metallurgical Site of La Cabane des Clausis*

A number of archaeological remains linked with metallurgical activities have been discovered on the site of the old Cabane des Clausis, situated on a platform about 350 m down from the mining zone (Barge, 1998). The first finds – in the form of a multiphase heap consisting of charred remains (charcoal and cinders) mixed in with slag – appeared in the ruins of the Cabane (a kind of shepherds' shelter which has since been restored). These deposits contained sandy material alternating with layers rich in combustion products. The existence of a modern foundation ditch for the Cabane des Clausis in this area meant that it has not been possible to establish the stratigraphic link between the waste materials and the combustion structure.

The extension of excavations to the whole of the terrace revealed the existence of a complex metallurgical site. The terrace is formed of different layers containing various quantities of combustion products and debris left over from the metallurgical treatment of the ore. In the absence of any combustion structure directly linked to this zone, the artefacts and products found on the site probably resulted more from activities such as crushing ores. The tools – consisting essentially of hammers, cupula stones and mortars – were used for ore enrichment and the crushing of slag and smelting products. The numerous fragments of clay tuyeres which were also discovered have a very particular shape: they are small, conical, and gradually become thicker and flare out at the end. They have a very small opening no more than 0.3 cm in diameter, with no apparent slag residue. Similar fragments were unearthed in the Pinilière

shelter next to the protohistoric mine, and in various other places in the valley. Pottery objects, probably for domestic use and provided with a ribbon handle and fingered strips, or decorated with bands, can be linked with the Early Bronze Age. The numerous dates obtained within the archaeological horizons support this hypothesis.

## The Early Bronze Age District Mining of the Grandes Rousses Massif

### *Dating of the Mining District's Operating*

The end of the 3<sup>rd</sup> millennium BC (24<sup>th</sup> and 23<sup>th</sup> century BC) certainly constitutes a break in the modalities of metallic properties's production and distribution. Research initiated by Marie-Christine Bailly-Maître (Bailly-Maître & Gonon, 2008), and nowadays managed by Joël Vital's team, confirms the exceptional nature of the mining district (Vital, 2009).

The mining district ranges on several stages of mountain's area, since surfaces located on an altitude of 2000 m, to the base of the wall localized at nearly 2700 m. Mineral veins are unfold over dozens hectares. Ores are usually formed of copper sulfide; they have been operated by the action of fire. The operating intensive nature is here clearly shown by the trench pillar, like at «Plan de Cavalle 4». This deep trench (several tens of meters) has exhausted the veins on a length of over 200 m. The systematic vein's exploitation is quite an outstanding phenomenon.

Four <sup>14</sup>C datations (Bailly-Maître & Gonon, 2008) could prop the beginning of the exploitation at the end of the 3<sup>rd</sup> millenium BC (over 2200 BC) (Fig. 2). The exploitation could be interrupted at the beginning of the Middle Bronze Age (over 17<sup>th</sup> century BC).

The discoveries made in the Grandes Rousses Massif (Oisans) by Christine Bailly-Maître are supporting the idea of a rise of copper resources's exploitation in the alpine area, at the beginning of Bronze Age (Bailly-Maître & Gonon, 2008).

### *Environmental Changes and Mining Activity: The Lake Bramant Sedimentary Record*

Lake Bramant is the third lake of a chain of high altitude (above 2448 m a.s.l.) proglacial lakes located in the Grandes Rousses Massif (western French Alps). It drains the Côte Blanc glacier and a difffluence of the St. Sorlin glacier in the Bramant valley and its sedimentation is thus strongly influenced by glacier fluctuations (Guyard et al., 2007).

Sub bottom acoustic profiling allowed optimizing the location of a long core retrieved in 2003 and covering the last 4000 years (Guyard et al., 2007). Combining varve counting and XRF measurements (on an ITRAX core scanner) and two radiocarbon ages (on terrestrial macro remains) this paper highlighted significant changes in sedimentation at the base of the core

(between 400 and 510 cm below lake floor, Fig. 4). In particular two organic rich units dated to the Early and Late Bronze age, respectively, were related to periods of reduced glacier activity resulting in a drop of the lake level. A clear peak of copper content in the sediments was also identified between 3770 and 3870 cal BP and related to atmospheric metallic contaminations induced by a mining activity recently documented by Bailly-Maitre & Conon (2008) near the catchment area of Lake Bramant in the Northern part of the Grandes Rousses Massif.

In order to further document environmental changes during the Bronze Age in this part of the massif, organic matter in the sediments has been characterized by Rock Eval pyrolysis and quantitative palynofacies investigations (Simonneau, 2009). These analyses allowed measuring Total Organic Carbon (TOC, %) together with spores and pollen content at several key periods. These new data highlight significant changes in TOC matching the Inc/Coh ratio variations given by ITRAX core scanner. These organic rich facies are also characterized by higher spores and pollens contents. These new findings, together with the exceptional occurrence of two terrestrial organic macro remains at the base of the core suggest that reduced glacier activity during the Early and Late Bronze Age were also associated with a change in the altitude of the timberline. To conclude, Lake Bramant proglacial sediments recorded significant environmental changes that probably favoured the development of mining activity at high altitude in this massif during the Early Bronze Age.

### Glacial Fluctuations and Exploitation of Copper Resources in High Mountain: A Deterministic Model?

The end of the 3<sup>rd</sup> millennium BC (24<sup>th</sup> and 23<sup>th</sup> century BC) surely establishes a big change in modalities of metallic properties' production and distribution. This change is not related to the development of alloys based on tin; it is more probably related to the appearance of innovations in the field of polymetallic ore metallurgy. At France scale, absolute chronology data remain scarce. But exploitations traces and metallurgical sites from the late Neolithic are providing datations with thin ranges of probability, centred on the end of the third millennium BC.

Dating of Saint Véran's mining and metallurgical sites (Hautes-Alpes) suggest a local metal production, from the second half of the third millennium and at the early second millennium BC (Carozza et al., in press). The beginning of the exploitation of "Les Rousses" mining district dates from the end of the 3<sup>rd</sup> millennium BC; it continues after the 18<sup>th</sup> century BC, probably until the early Middle Bronze age.



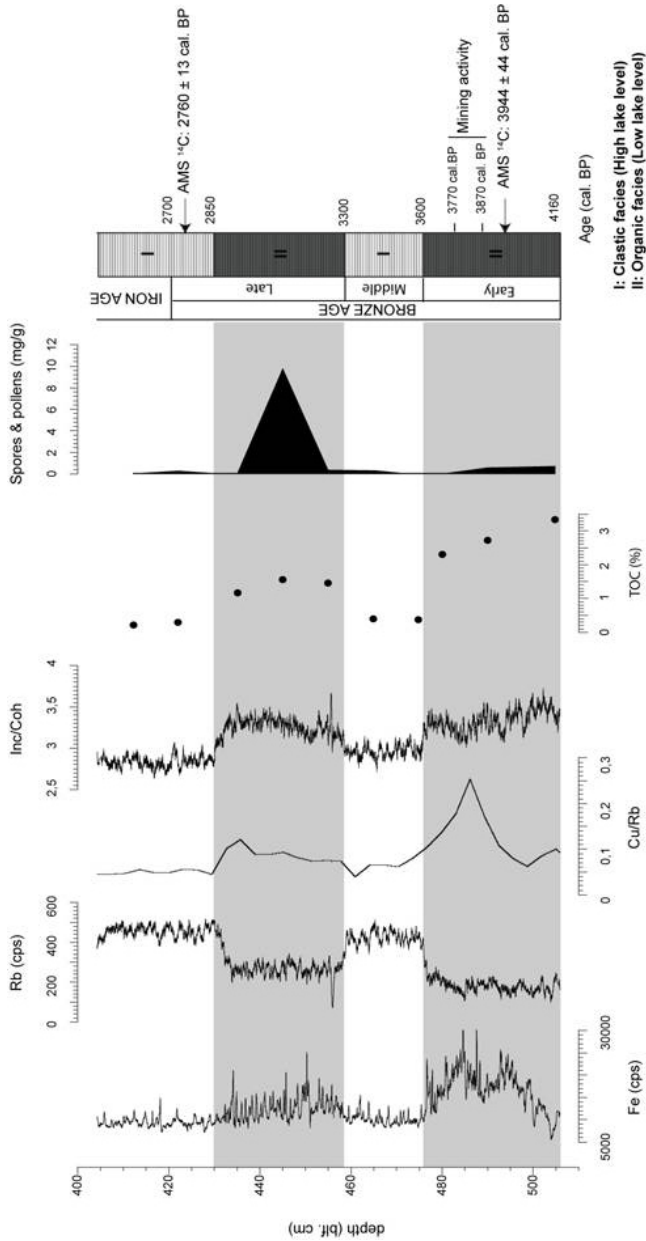


Fig. 4: Multiproxy signature of high altitude environmental changes during the Bronze Age in proglacial lake Bramant, combining varve counting, radiocarbon dating on terrestrial macro remains, XRF core scanning (counts related to Fe, Rb and Cu, Inc/Coh ratio) and organic geochemistry (Total Organic Carbon, TOC; quantitative optical characterisation of organic particles characteristical for spores and pollens). This data set highlight a peak in Cu content during the Early Bronze Age in an organic facies suggesting that mining activities in the massif were favoured by reduced glaciers and the development of vegetation above 2500 m a.s.l..

While the slight increase of Cu/Rb in organic facies may be of diagenetic origin, the peak of Cu/Rb identified at the base of the core and dated between 3870-3770 cal. BP (Guyard et al., 2007) is interpreted as resulting from a coeval ( $3800 \pm 100$  cal. BP) and closed copper mining activity (e.g. Bailly-Maitre & Gonon, 2006). This regional high altitude and recently discovered mining activity, developed between 2300 and 2650 m a.s.l., has probably been possible because of smaller glaciers and a vegetation change in the massif due to warmer climate during the Early Bronze Age.

The environmental data synthesis displays, in the long term, interactions between human activities and environmental changes at high altitude. Major climate change's tendencies characterize the Bronze Age in the Alps with two warm episodes: the first one during the early Bronze Age (4160-3600 cal BP or 2200-1650 BC); the second one during the early final Bronze Age (3300-2850 cal BP or 1350-900 BC).

These two Bronze age's stages transpose a significant change in the vegetation around an altitude of 2500 m.

Conditions of transition from a Neolithic technical system (local network) to a Bronze Age model are nowadays based on well known criteria: increased use of metal, adoption of bronze (which is an alloy of copper and tin able to greatly improve the metal's properties). It is then necessary to handle the increasing pressure on copper resource.

Western Alps are obviously a major area to study across from the spectacular development of the Rhone valley. Data converge nowadays to show that the exploitation of copper resources in high altitude is closely related to the glacial abandonment. Western Alps are characterized by a global warming at the early Bronze Age. Thus, they are well placed to respond at the new and growing copper needs of the first Bronze Age societies.

This model could display a thin correlation between climatic changes and metallic's resource provision in High Mountain (2300-2600 m). This exploitation was made possible by the decline of small glaciers after several global warming episodes.

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