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Study of an Etruscan object composed of three metals

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ABSTRACT. — This paper reports the results of preliminary research carried out on one of the many metal objects from excavations in the Sanctuary of Pyrgi (Santa Severa, Rome) near the port of Caere (Cerveteri), one of the main towns of Southern Etruria. The metal object, found in the southern area of the sanctuary consists of a cylinder, perhaps a handle, originally part of an object of indefinite shape and function. It consists of three different layers of metal: a central ferrous rectangular rod (10 × 8 mm), surrounded by a thick lead alloy ring 21 mm in diameter, and a 2-mm outer layer of copper alloy. SEM+EDS analyses were carried out on the three components.

It seems probable that the outer copper alloy sleeve was produced first. The inner iron rod was set in position and the Pb-Sn alloy was then cast to fix all three parts of the object together.

The ferrous rod was produced by deformation resulting from heating. Pb- and Cu-bearing alloys were cast in temperature ranges of, respectively, 350-300°C and 1100-800°C.

RIASSUNTO. — Si presentano i risultati delle indagini preliminari eseguite su uno dei numerosi reperti metallici provenienti dagli scavi diretti dal prof. Giovanni Colonna dell'Università di Roma «La Sapienza» nel santuario di Pyrgi (Santa Severa – Roma), sito presso il porto di Caere (Cerveteri), una delle principali città dell'Etruria meridionale.

Si tratta di un elemento cilindrico, forse un'impugnatura, parte di un oggetto dalla forma e dalla funzione non precisabile, rinvenuto nell'area Sud del santuario, la cui documentazione, comprendente una cospicua quantità di offerte votive databili per lo più tra il V e il IV sec. a.C., testimonia la continuità del culto fino a tutto il III sec. a.C.

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INTRODUCTION AND HISTORICAL BACKGROUND

This paper presents the results of preliminary research carried out on one of the numerous metal objects found in the excavations directed by Prof. Giovanni Colonna of the University of Rome «La Sapienza», in the southern area of the Etruscan Sanctuary of Pyrgi (Santa Severa, Rome), the main harbour of Caere (Cerveteri), as a contribution towards knowledge of metal production in South Etruria (Figs. 1, 2).

The findings in this area of the Sanctuary, which include a large number of votive offerings mainly dating from the 5th and 4th centuries BC, bear witness to constant worship up to the end of the 3rd century BC (Baglione, 1989-90; Colonna, 1992, 1996; Colonna and Baglione, 1998).

The object of this study, perhaps a handle with its ends missing, is part of an artefact, the shape and function of which cannot yet be identified. It is formed of a cylindrical part in lead in a bronze sleeve and an iron rod, with a

Fig. 1 – Aerial view of Sanctuary of Pyrgi.

Fig. 2 – Aerial view of southern part of Sanctuary of Pyrgi.

square cross-section, probably running from one end to the other. The rod is visible protruding from the end of the artefact. The detail of a lead core coated by a bronze sleeve is typical, for example, of the handles of round shields of rolled bronze, in use from a very advanced phase of the First Iron Age (second half of 8th century BC).

The technical characteristics of the object are extremely interesting, because it is an example of composite metallurgy, i.e., different metals and alloys in juxtaposition.

Its main interest lies not only in the use in the same object of three different metals but also of the alloy – iron, lead and bronze – mostly represented in the Sanctuary of Pyrgi in several kinds of materials, already extensively studied (Drago *et al.*, 1999, 2000 a, 2000 b; Cavallini *et al.*, 2000).

Among the iron objects there is also a large group of arrow-heads – more than five hundred – found in the fill of the square of the southern area of the Sanctuary, together with large numbers of Attic ceramics and other metal and ceramic findings. These objects form a sort of large secondary votive deposit, sealed at the latest at the mid-4th century BC, and have been related to the god *Suri*, corresponding to the Faliscan god *Apollo Soranus*, the Greek *Hades*, the Latin *Dis Pater* and the Roman *Vediovis*.

Among the findings, ten lead ingots are of particular interest. They are prismatic in shape, have a more or less regular trapezoidal cross-section, and weigh between 5,300-6,400 kg. and 21,750-38,500 kg. They were found in the southern area of the Sanctuary, under the foundations of altars and buildings dedicated to Suri in the 5th century BC. They are similar in composition but not in shape to the small lead ingots from the archaic wreck found at Campese Bay (Isola del Giglio) (Bound, 1991; Craddock and La Nieci, 1991; Cristofani, 1998).

Other lead objects found in the northern and southern areas of the Sanctuary are many clamps and lead pieces, partly used to fasten terracotta decorations to the wooden parts of the temples, and numerous «missili» (so called «ghiande missili»), dating from the 5th and 3rd centuries BC. Bronze goods include tools and vases. Among the findings in copper, most noteworthy is a significant group of pieces of *aes rude*, mainly found in the square of the southern area.

The aim of analyses, so far carried out on samples of the main categories of metal findings from both northern and southern areas (iron weapons, *aes rude*, ingots, clamps, lead missiles) and on a sample from the object examined here, is to gain information on metallurgy techniques and to determine the provenance of the raw materials, within the broader framework of a study on metallurgy, sources of supply, and circulation of raw materials in South Etruria (Tanelli, 1983, 1989; Zifferero, 1991, 1996; Carancini, 1996; Giardino, 1996, 1998; Boni *et al.*, 2000; Brocato, 2000;). Lead isotopes ($^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$, $^{208}Pb/^{204}Pb$) have been analysed in many lead objects from various parts of the Italian peninsula. Etruscan lead ingots from the Pyrgi temple (Caere, 5th century BC) show isotopic fingerprints of the mining district of southern Tuscany (Boni *et al.*, 2000).

Methods and Techniques

Fig. 3 shows the metal object. A transversal thin metallographic section was cut from it by a diamond saw and embedded in epoxy-type «Mecaprex MA2» cold mounting resin. Because of the great brittleness of the outer sleeve of the object, many chips were produced and lost during cutting.

Fig. 4 shows an overall view of the specimen, which was examined by optical microscopy. It was then sputtered with a thin film of carbon produced by evaporation, for Scanning Electron Microscopy (SEM) + Energy Dispersion Spectroscopy (EDS) analyses.

Quantitative analyses were carried out for information on the various components, impurities, and interphases between metals, where corrosion effects are more interesting.

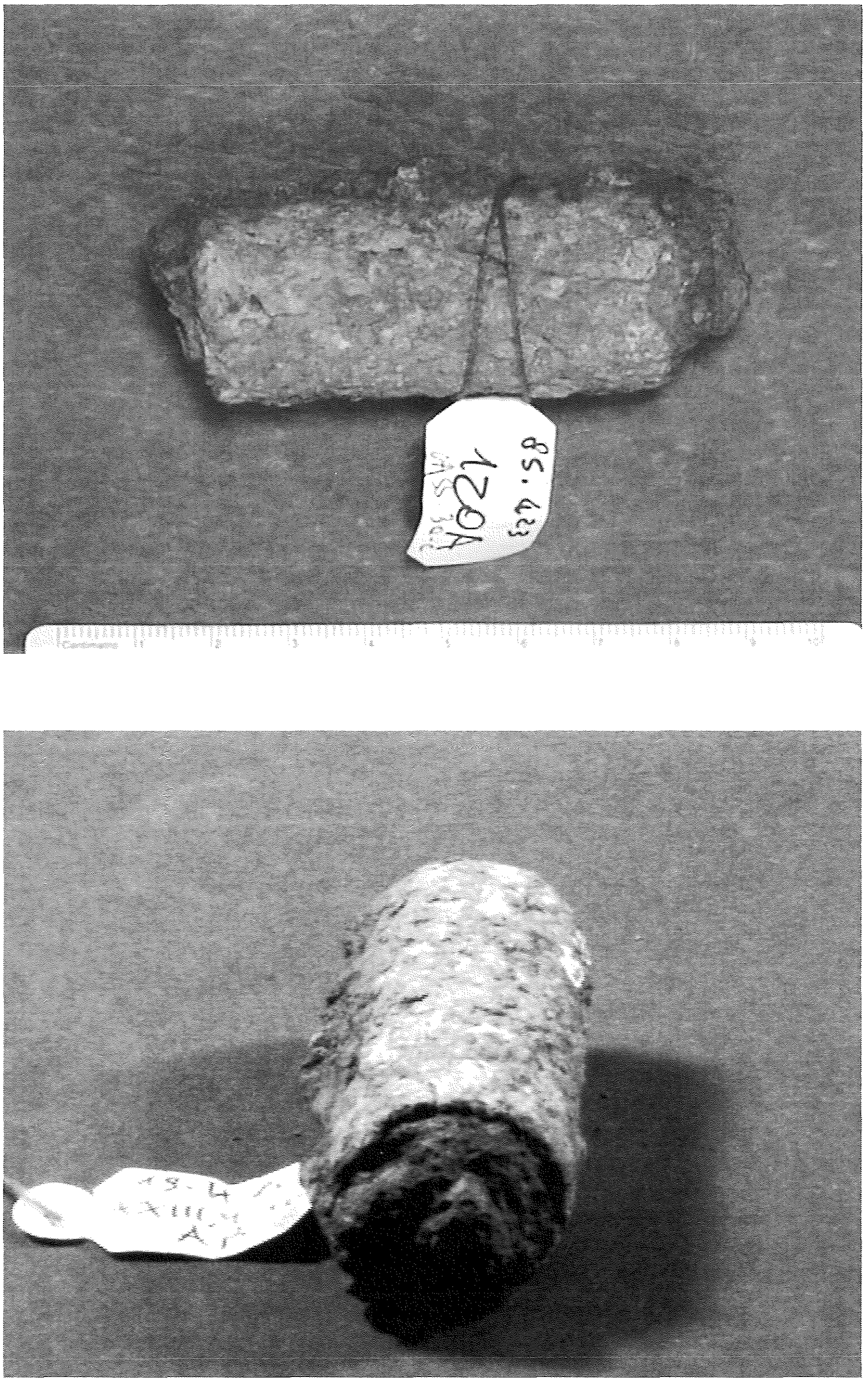

Fig. 3 – Two aspects of studied object.

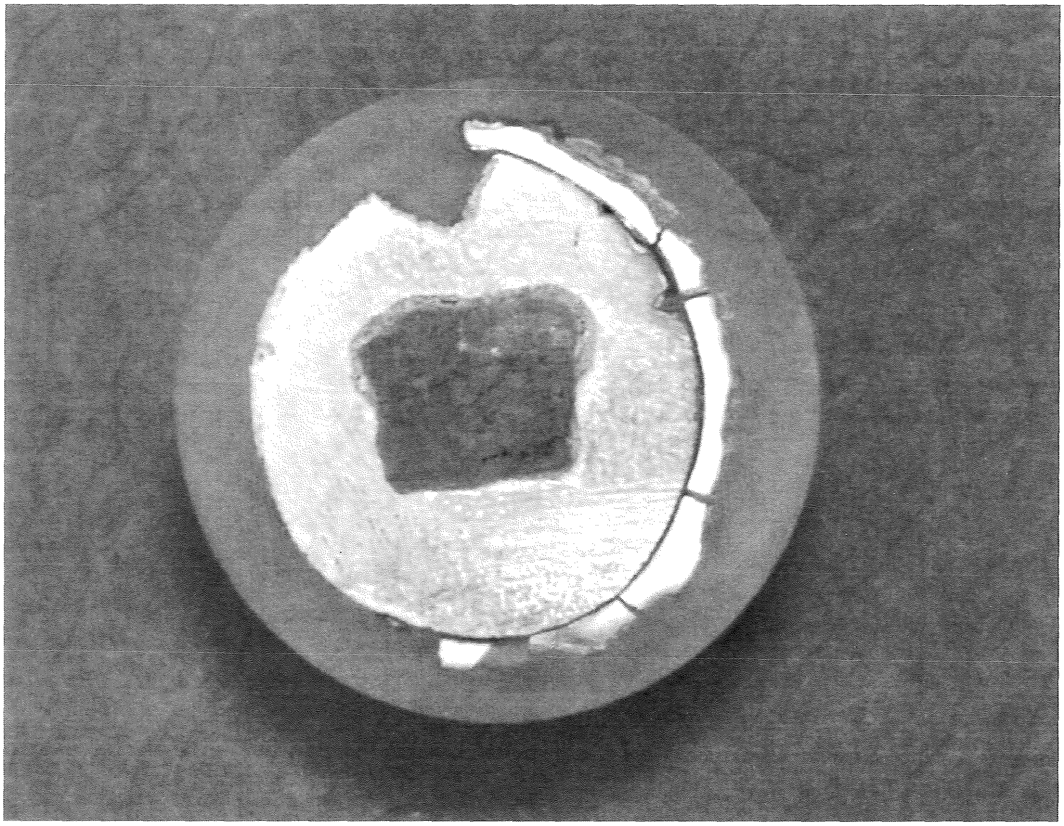

Fig. 4 – Transversal section of object embedded in resin.

Results

EDS analyses of the outer ring show that it is made of bronze, with the following composition: 84.1% Cu, 13.9% Sn, 1.8% Pb, 0.2% Fe. Corrosion morphology is clearly shown in fig. 5, in which a penetration of about 1 mm is evident. Metallographic examination reveals a heterogeneous pattern of dendrites (α_{Cu} solid solution) and $\alpha+\delta$ eutectoid areas. The darker constituent in fig. 6 is α_{Cu}, with maximum Sn contents of 4%; the lighter constituent is an $\alpha+\delta$ eutectoid with Sn contents over 20%. Pb is associated mainly with the δ phase. The X-ray map of Cu and Sn is also shown in fig. 6. The dendritic structure clearly indicates that the sleeve was produced by a casting technique.

A thin layer of metallized iron was detected at the interface with the inner ring (fig. 5), which consists of a Pb-Sb alloy with 1.1% Sb and about 0.5% Cu.

The central ferrous rod appears to be fully mineralized, as usually occurs, and consists of various oxidation products (iron oxides, oxyhydroxides). The whole rod presents many cracks particularly at the Fe-Pb interface, as shown in fig. 7. Silicon and aluminium-rich inclusions are shown in fig. 8.

Discussion and Conclusions

Metallographic and analytical results suggest how the object was made. Some indications about ancient mines will also be discussed.

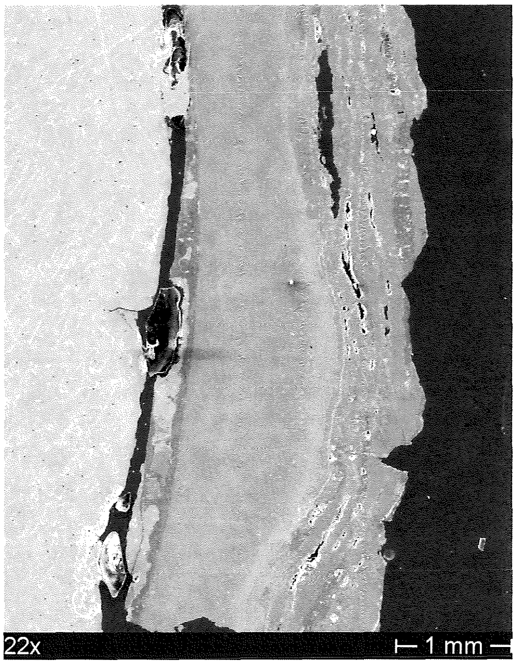

Fig. 5 – SEM micrograph of outer bronze ring. External surface shows corrosion products; internal interface towards Pb-Sb alloy is still metallic, with mineralized iron layer.

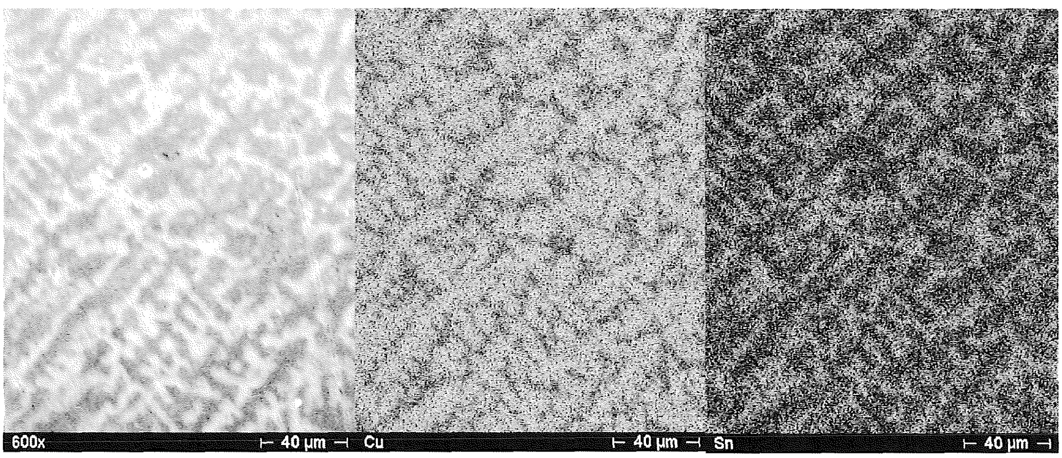

Fig. 6 – Micrograph of dendritic structure of bronze, and X-ray map of Cu and Sn.

The outer bronze ring was produced first. The presence of dendritic structures suggests casting of a (lost wax?) plane sheet with a rougher inner surface, worked while hot on a barrel to give a cylindrical shape. The loss of continuity in the cylindrical ring but the presence of an overlap along a generatrix, support this idea. The thin layer of mineralized iron, found at the bronze-lead interface, is probably due to deposits of iron-rich corrosion products from the inner rod or to corrosion of local residues from the working process.

The inner iron rod was set in position and the Pb-Sb alloy was then cast, to fix the parts of the whole object together.

As regards the metals:

– the outer bronze sleeve is a typical Cu-Sn alloy with low Pb contents. It appears to be homogeneous and has few inclusions. The alloy is quite different from the previously studied *aes rude* found in the same site (Drago *et al.,* 2000 b), which consisted of metallic copper with mixed iron and copper sulphides, and other lead and bismuth impurities;

– the Pb-Sb alloy is very similar in composition to previously studied ingots (Drago *et al.,* 2000 a), suggesting that its ore came from typical regional mineralized areas like the mountains of Tolfa or southern Tuscany, where galena with such a composition was mined (Rolandi, 1956; Tanelli, 1983, 1989; Zifferero, 1991, 1996; Carancini, 1996; Giardino, 1996, 1998; Saez *et al.,* 1996; Brocato, 2000).

– the morphology of the mineralized iron is different from that of the iron arrow-heads from the same site (Cavallini *et al.,* 2000), as its inclusion contents consist of Si- and Al-rich products, typical of local ores, instead of the puzzling Ca-rich inclusions of the arrow-heads (Panseri, 1957; Follo *et al.,* 1988; Gauzzi *et al.,* 1996; Mapelli and Nicodemi, 2000).

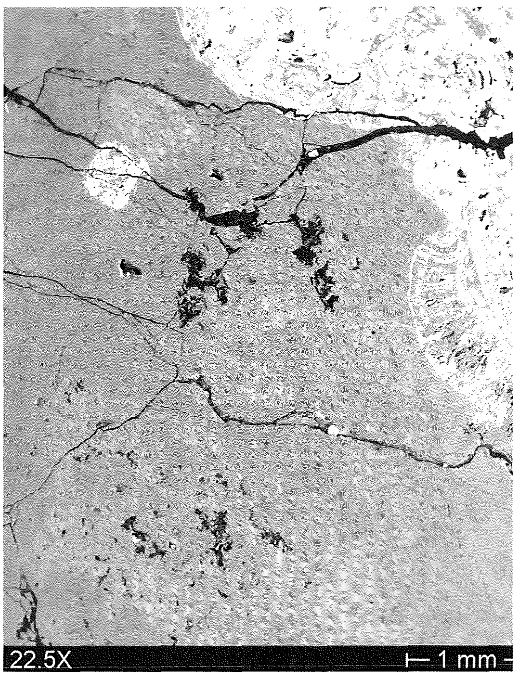

Fig. 7 – Micrograph of interface between mineralized Fe and Pb-Sb alloy.

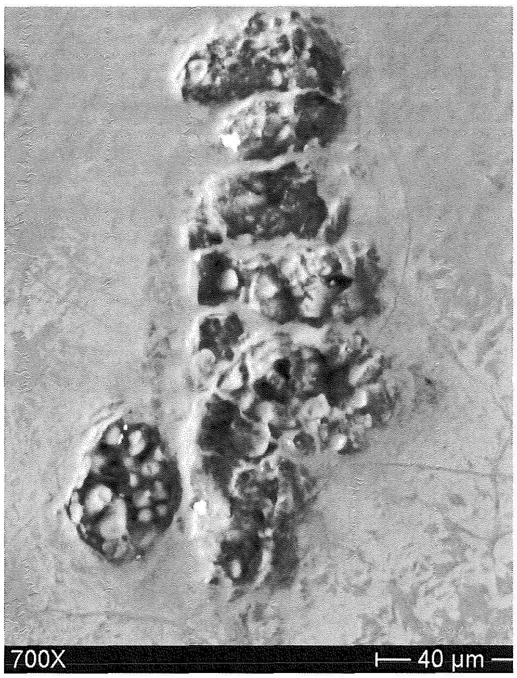

Fig. 8 – Silicon- and aluminium-rich inclusions inside mineralized iron rod.

It should not be forgotten that the three alloys studied here differ greatly from the technological point of view: the iron rod was produced by hot deformation, whereas the Pb- and Cu-bearing alloys were cast in temperature ranges of, respectively, 350-300°C and 1100-800°C. The temperature of iron reduction was not higher than that of the copper alloy, because direct reduction was involved, with no need to reach melting temperature (1536°C for pure iron).

This study of an Etruscan object composed of three metals confirms the high metallurgical skills (Tylecote, 1988) of the old craftsmen, who were capable of handling different kinds of alloys. Knowledge of very different techniques and ores coming from several mines confirm the metallurgical and commercial ability of the Etruscans.

REFERENCES

BAGLIONE M.P. (1989-90) — *Considerazioni sui santuari di Pyrgi e di Veio-Portonaccio.* Scienze dell'Antichità, 3-4, pp 651-657.

BONI M., VILLA I.M., BENVENUTI M., DI MAIO G. and SAVIANO G., (2000) — *Greeks, Etruscans, Italics and Romans: the impact of Pb-isotope analyses on traditional archaeology in peninsular Italy.* Geol. Soc. Am., Abstract, Reno, November 2000, **32**, 1.

BOUND M. (1991) — *The pre-classical wreck at Campese Bay, Second Interim report. In Studi e Materiali.* Scienza dell'Antichità in Toscana VI, Firenze: 199-243.

BROCATO G. (2000) — *Lineamenti geoarcheologici sulle antiche attività estrattive relative ai minerali di alunite e metallici nel bacino minerario dei Monti della Tolfa.* In: Metalli, Miniere e Risorse Ambientali - Il territorio dei Monti della Tolfa tra medioevo ed età contemporanea. Atti del Convegno di studio: «Le attività metallurgiche e minerarie della Reverenda Camera Apostolica nell'area di Allumiere e Tolfa». Franca Fedeli Bernardini (ed.), Rome 2000, 9-11.

CARANCINI G.L. (1996) — *Metallurgia e società nell'Italia protostorica.* In: Piola Caselli P., Piana Agostinetti P. eds. «La miniera, l'uomo e l'ambiente. Fonti e metodi a confronto per la storia delle attività minerarie e metallurgiche in Italia», Firenze: 287-304.

CAVALLINI M., DRAGO L., FELLI F. and SAVIANO G. (2000) — *Indagini archeometallurgiche su manufatti in ferro dal santuario etrusco di Pyrgi.* In: Proceedings 28° Convegno Nazionale AIM, Milan, **2**, 617-624.

COLONNA G. and BAGLIONE M.P. (1998) — *Il santuario etrusco di Pyrgi.* In: Drago Troccoli L. (ed.), Scavi e ricerche archeologiche dell'Università di Roma «La Sapienza», Rome, 125-135.

COLONNA G. (1992) — *Altari e sacelli. L'area sud di Pyrgi dopo otto anni di ricerche.* Rend. Pont. Ac. **64**, 63-115.

COLONNA G. (1996) — *Pyrgi.* In: Enciclopedia dell'Arte Antica, II suppl., IV, Roma: 678-684.

CRADDOCK P.T. and LA NIECI S. (1991) — *Report on the composition of corroded metal fragments from the pre-classical wreck at Campese Bay. Addendum a* BOUND M. 1991. In: Studi e materiali. Scienza dell'Antichità in Toscana VI, Firenze: 242-243.

CRISTOFANI M. (1998) — *Un naukleros greco-orientale nel Tirreno. Per un'interpretazione del relitto del Giglio.* In: Annuario della Scuola Archeologica di Atene e delle missioni italiane in Oriente, 70-71, n.s., 54-55 (1992-93), 205-231.

DRAGO L., FELLI F. and SAVIANO G. (2000) — *Indagini archeometallurgiche preliminari su manufatti in piombo provenienti dal santuario etrusco di Pyrgi.* Boll. Acc. Gioenia Sci. Nat., **33**, 249-260.

DRAGO L., FELLI F. and SAVIANO G. (2000 B) — *Indagini archeometallurgiche su manufatti in piombo rame e bronzo dal santuario etrusco di Pyrgi.* In: Proceedings 28° Convegno Nazionale AIM, Milan, **2**, 659-666.

DRAGO L., PLESCIA P. and PAGLIETTI F. (1999) — *Non-destructive testing on cultural heritage using portable XRD and XRF spectrometers.* In: Art '99, 6th International Conference of Non-Destructive Testing and Microanalysis for the Diagnostics and Conservation of the Cultural and Enviromental Heritage, Rome, May 1999, 1863-1874.

FOLLO L., GARAGNANI G., POLI G. and SPINEDI P. (1988) — *Metallurgical investigation on some iron objects of particular arcaeological interest.* In: Pact 21, 133-147.

GAUZZI F., VERDINI B., PRINCIPI G., GUPTA R., RACCANELLI A. and RUSSO U. (1996) — *Structural study of an Etruscan axe.* In: Proceedings of ICAME 95, I. Ortali (ed.), SIF, Bologna.

GIARDINO C. (1996) — *Dal manufatto al minerale. Possibilità e limiti delle analisi archeometallurgiche: rame e sue leghe, argento, piombo.* In: Piola Caselli P., Piana Agostinetti P.

(eds.) «La miniera, l'uomo e l'ambiente. Fonti e metodi a confronto per la storia delle attività minerarie e metallurgiche in Italia». All'Insegna del Giglio, Firenze: 53-76.

GIARDINO C. (1998) — *Metalli nel mondo antico. Introduzione all'archeometallurgia*, Laterza, Roma-Bari.

MAPELLI C. and NICODEMI W. (2000) — *Ipotesi sulle condizioni termodinamiche del processo etrusco per la riduzione del minerale in ferro.* La Metallurgia Italiana. **1**, 13-19.

PANSERI C. (1957) — *La tecnica di fabbricazione delle lamine di acciaio presso gli antichi.* AIM, Quaderno II, Milan.

ROLANDI G. (1956) — *Il Piombo.* Edizioni della Rassegna L'Industria Mineraria. Faenza, 165 pp.

SAEZ R., ALMODOVAR G.R. and PASCUL E. (1996) — *Geological constraints on massive sulphide genesis in the Iberian Pyrite belt.* Ore Geol. Rev. **11**, 429-451.

TANELLI G. (1983) — *Mineralizzazioni metallifere e minerogenesi della Toscana.* Mem. Soc. Geol. It., **25**, 91-109.

TANELLI G. (1989) — *I depositi metalliferi dell'Etruria e le attività estrattive degli etruschi.* In: «Atti del Secondo Congresso Internazionale Etrusco», Firenze, vol. III, 1409-1417.

TYLECOTE R.F. (1988) — *Extraction metallurgy: historical development and evolution of the processes.* In: Atti del Colloquio Internazionale di Archeometallurgia. Editrice CLUEB, Bologna, 25-51.

ZIFFERERO A. (1991) — *Miniere e metallurgia estrattiva in Etruria meridionale: per una lettura critica di alcuni dati archeologici e minerari.* Studi Etruschi, LVII: 201-241.

ZIFFERERO A. (1996) — *Archeologia in miniera: un itinerario archeominerario nel Lazio settentrionale.* In: Piola Caselli P., Piana Agostinetti P. (eds.) La miniera, l'uomo e l'ambiente. Fonti e metodi a confronto per la storia delle attività minerarie e metallurgiche in Italia, Firenze: 239-258.