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COMMENTS . . . III

E. PERNICKA

Max-Planck-Institut für Kernphysik, Postfach 103980, D-6900 Heidelberg, Germany

The discussion on the evaluation of lead isotopic data (Gale and Stos-Gale 1992; Leese 1992; Pernicka 1992; Reedy and Reedy 1992; Sayre *et al.* 1992b), timely and welcome as it is, seems to go somewhat astray. Much emphasis is given to technicalities of the statistical treatment of the data but surprisingly little attention is paid to the geological and geochemical framework of lead isotope compositions of ores and the archaeological questions that are addressed with this methodology. Therefore, this comment will concentrate on these two topics trusting that, as long as lead isotope compositions continue to be published in the form of abundance ratios, these will be used rather than isotopic abundances. It should be remembered that one significant advantage of LIA over trace element studies is the simplicity with which comparisons among artefacts and beween artefacts and ores can be made. There is, in fact, hardly any need for multivariate statistical methods at all. Searching for subtle differences in various projections of the data is likely to lead to overinterpretation.

Despite assertions to the contrary, no convincing case has yet been presented where multivariate statistical methods revealed more information than the two diagrams $^{208}Pb/^{206}Pb$ versus $^{207}Pb/^{206}Pb$ and $^{204}Pb/^{206}Pb$ versus $^{207}Pb/^{206}Pb$, if one takes into account the errors of the individual measurements. Our somewhat ironical remark that more LIA of ore sources will lead to more ambiguity (Pernicka *et al.* 1990) was meant as a plea to accept the obvious and to give in to reality. Of course, we did not suggest that one should not strive for a more complete characterization of ore sources, as Sayre *et al.* (1992b) have implied. It is simply unrealistic to pretend that a unique characterization of ore deposits will eventually be possible, if one would only use more sophisticated methods of data analysis. It is gratifying to note that this view is also shared by others (Budd *et al.*).

ARTEFACTS

Archaeologists usually work with a coherent set of artefacts, either from one site in a diachronous study or with one typological unit from a wider area in a synchronous investigation. In the first type of study a typical question relates possible changes of technology and/or raw materials that may accompany typological changes. In the second class of study it is often of primary interest to see if two typologically indistinguishable artefacts are actually made of the same starting materials, but ultimately the location of ore sources is also desirable. In any case, there is ideally an archaeological concept or a hypothesis at the outset of a lead isotope study, and LIA is at its best when it is applied for such restricted problems of classification and testing of a hypothesis. In this respect the problem of the origin of Troad metallurgy was an ideal one because two mutually excluding hypotheses could be tested (Pernicka *et al.* 1984 and 1990; Begemann *et al.* 1992). Alternatively, one could ask if and to what extent the isotopic and chemical fingerprint of a dated mine such as Aibunar in Bulgaria (Gale *et al.* 1991) and Rudna Glava in Serbia (Pernicka *et al.* 1993) is reflected in the metal of contemporary artefacts from its surroundings. It is, however, not clear which archaeological hypothesis was to be tested in the papers by Yener *et al.* (1991) and Sayre *et al.* (1992a). Simply comparing a heterogeneous set of metal artefacts, regardless of their composition, geographical provenance, or archaeological context with any ore source in the eastern Mediterranean, regardless of its mineralogy, is unyielding, to say the least. The reply of Sayre *et al.* (1992b) to this criticism, which was also raised by Gale and Stos-Gale (1992), is unsatisfactory. The reader is entitled to a correct interpretation by the specialist. How should a non-specialist know that silver and lead could never have been produced on Kythnos or Cyprus from local ores? In this context, such a comparison is actually misleading.

ORE DEPOSITS

Many ore deposits are multimetallic in nature, and it is generally to be expected and has, in fact, been proven many times (see e.g. Wagner *et al.* 1989 for a summary) that different minerals within one deposit have the same lead isotope composition. Obviously, the argument cannot be reversed, that is ore samples having the same lead isotope composition are not necessarily of the same deposit. However, Yener *et al.* (1991) did just that. Their Taurus 1B field comprises samples from Kestel, basically a small iron ore deposit containing some gold and possibly some tin but no copper and lead, together with samples from a mineralized vein containing galena with some fahlore at Sulucadere in the Bolkardag area. From the text it is not at all clear that the point was to show that the Kestel mine matches the Taurus 1B field as maintained by Sayre *et al.* (1992b). It rather appears that the samples from Kestel and Bolkardag, which are some 50 km apart and emplaced in different tectonic complexes, together define the Taurus 1B field. The reasoning was that besides having similar lead isotope ratios, ore samples from both sites are from high altitudes and contain tin. One can only conclude that the authors hint at a genetic relationship which seems very strange, since tin and lead deposits (not traces) usually occur in very different geological environments. Concerning the tin contents of the 'cassiterite' samples AON 399, 463, and 466 from the Kestel mine, it would have been helpful, if not necessary, to provide the information that LIA were made on extracted cassiterite (Sayre *et al.* 1992b) in the sample description of the original publication (Yener *et al.* 1991). The reader cannot be blamed for this omission.

One basic assumption in the statistical treatment of lead isotope data is an approximately normal distribution and Sayre *et al.* (1992a) felt justified to exclude 'outliers' which would not fit this distribution. It now emerges that copper ores containing also uranium and/or thorium may be much more common than is usually assumed (e.g. Gale and Stos-Gale 1992). If combined with low lead concentrations, the radiogenic lead from the decay of uranium and thorium within the deposit can measurably alter the isotopic composition of the lead, which thus may depend on the variation of the (U, Th)/Pb ratio in the deposit. The net result is that the original isotopic composition of the lead from the formation of the deposit is shifted by varying amounts towards the lower left in a diagram $^{208}Pb/^{206}Pb$ versus $^{207}Pb/^{206}Pb$. If only one such sample were to be measured, it would surely be regarded as 'outlier'. This effect was first noted in a copper artefact from Troia (Pernicka *et al.* 1984) but it has since been observed at Ergani Maden (Seeliger *et al.* 1985), Feinan (Hauptmann *et al.* 1992), and Rudna Glava (Pernicka *et al.* 1993). Other important deposits, at least from the archaeological point of view, which have not yet been analysed by LIA, like Talmessi and Meskani on the Iranian plateau, are known to contain uranium minerals (Schürenberg 1963).

In summary, for characterizing an ore source for provenance studies of archaeological metal objects much more geological, mineralogical, and geochemical information is needed than was hitherto considered necessary. It is not enough to measure 20 samples of a small ore vein to satisfy statistical requirements. Instead, one should strive to collect as much information as possible on an ore body from the pertinent literature and from observations in the field. Only then is adequate sampling possible.

REFERENCES

Begemann, F., Schmitt-Strecker, S., and Pernicka, E., 1992, The metal finds from Thermi III–V: a chemical and lead isotope study, *Studia Troica*, **2**, 219–39.

Gale, N. H., Stos-Gale, Z. A., Lilov, F., Dimitrov, M., and Todorov, T., 1991, Recent studies of Eneolithic copper ores and artefacts in Bulgaria, in *Découverte du métal* (eds J.-P. Mohen and C. Éluère), 49–75, Paris.

Gale, N. H., and Stos-Gale, Z. A., 1992, Evaluating lead isotope data: comments on E. V. Sayre, K. A. Yener, E. C. Joel and I. L. Barnes, 'Statistical evaluation of the presently accumulated lead isotope data from Anatolia and surrounding regions', . . . , I, *Archaeometry*, **34** (2), 311–16.

Hauptmann, A., Begemann, F., Heitkemper, E., Pernicka, E., and Schmitt-Strecker, S., 1992, Early copper production at Feinan, Wadi Arabah, Jordan, *Archeomaterials*, **6**, 1–33.

Leese, M. N., 1992, Evaluating lead isotope data: comments on E. V. Sayre, K. A. Yener, E. C. Joel and I. L. Barnes, 'Statistical evaluation of the presently accumulated lead isotope data from Anatolia and surrounding regions', . . . , II, *Archaeometry*, **34** (2), 318–22.

Pernicka, E., 1992, Evaluating lead isotope data: comments on E. V. Sayre, K. A. Yener, E. C. Joel and I. L. Barnes, 'Statistical evaluation of the presently accumulated lead isotope data from Anatolia and surrounding regions', . . . , III, *Archaeometry*, **34** (2), 322–6.

Pernicka, E., Seeliger, T. C., Wagner, G. A., Begemann, F., Schmitt-Strecker, S., Eibner, C., Öztunali, Ö., and Baranyi, I., 1984, Archäometallurgische Untersuchungen in Nordwestanatolien, *Jahrb. Römisch-Germanischen Zentralmuseums Mainz*, **31**, 533–99.

Pernicka, E., Begemann, F., Schmitt-Strecker, S., and Grimanis, A. P., 1990, On the composition and provenance of metal artefacts from Poliochni and Lemnos, *Oxford J. Archaeol.*, **9**, 263–98.

Pernicka, E., Begemann, F., Schmitt-Strecker, S., and Wagner, G. A., 1993, Eneolithic and Early Bronze Age copper artefacts from the Balkans and their relation to Serbian copper ores, *Prähistorische Zeitschrift* (in press).

Reedy, C. L., and Reedy, T. S., 1988, Lead isotope analysis for provenance studies in the Aegean region: a reevaluation, in *Materials issues in art and archaeology* (eds E. V. Sayre, P. Vandiver, J. Druzik and C. Stevenson), 65–70, Materials Res. Soc., **123**, Pittsburgh.

Reedy, C. L., and Reedy, T. S., 1992, Evaluating lead isotope data: comments on E. V. Sayre, K. A. Yener, E. C. Joel and I. L. Barnes, 'Statistical evaluation of the presently accumulated lead isotope data from Anatolia and surrounding regions', . . . , IV, *Archaeometry*, **34** (2), 327–30.

Sayre, E. V., Yener, K. A., Joel, E. C., and Barnes, I. L., 1992a, Statistical evaluation of the presently accumulated lead isotope data from Anatolia and surrounding regions, *Archaeometry*, **34** (1), 73–105.

Sayre, E. V., Yener, K. A., and Joel, E. C., 1992b, Evaluating lead isotope data: comments on E. V. Sayre, K. A. Yener, E. C. Joel and I. L. Barnes, 'Statistical evaluation of the presently accumulated lead isotope data from Anatolia and surrounding regions', Reply, *Archaeometry*, **34** (2), 330–6.

Schürenberg, W., 1963, Über iranische Kupfererzvorkommen mit komplexen Kobalt-Nickelerzen, *N. Jb. Min. Abh.*, **99**, 200–30.

Seeliger, T. C., Pernicka, E., Wagner, G. A., Begemann, F., Schmitt-Strecker, S., Eibner, C., Öztunali, Ö., Baranyi, I., 1985, Archäometallurgische Untersuchungen in Nord- und Ostanatolien, *Jahrb. Römisch-Germanischen Zentralmuseums Mainz*, **32**, 597–659.

Wagner, G. A., Begemann, F., Eibner, C., Lutz, J., Öztunali, Ö., Pernicka, E., and Schmitt-Strecker, S., 1989, Archäometallurgische Untersuchungen an Rohstoffquellen des frühen Kupfers in Ostanatolien, *Jahrb. Römisch-Germanischen Zentralmuseums Mainz*, **36,** 637–86.

Yener, K. A., Sayre, E. V., Joel, E. C., Özbal, H., and Barnes, I. L., 1991, Stable isotope studies of central Taurus ore sources and related artefacts from eastern Mediterranean Chalcolithic and Bronze Age sites, *J. Archaeol. Sci.*, **18**, 541–77.