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## Neutron-Activation Analysis Applied to Copper Ores and Artifacts

An adaptation of neutron-activation analysis for quantitative identification of impurities in copper is reported (ref. 1). The resultant data were used for determination of whether or not an "overall regional impurity pattern" in copper ores exists in a given area of Michigan.

One mystery perplexing archeologists is the copper missing from Michigan. Approximately 4000 years ago an enormous amount (between 0.5 and 1 billion pounds) of relatively pure copper was mined and carried away from the isolated regions around Lake Superior; the only clues left behind were crude tools. The method of mining consisted in building fires to heat rocks that were then cracked by dowsing with cold water. Ten thousand men must have labored in this region for more than 1000 years; they must have been intelligent and had good reason for wanting copper. Discovery of where the copper went might unravel the mystery.

The approach being used is to seek a unique fingerprint of trace metals in Michigan copper and to find artifacts somewhere in the world bearing this fingerprint. More generally, establishment of a distinctive fingerprint for each copper region in the world would enable identification of the source of any copper artifact.

Earlier research had shown the impurity in metallic copper to be related to the geographic origin of the copper ore for many samples from the East Alpine area that were analyzed spectrographically. Absolute concentrations varied considerably in any one deposit, but an overall regional-impurity pattern was found to characterize an area.

This present project tried to determine whether Michigan has a unique fingerprint, and the variation in concentrations of trace impurities in the same

Michigan mine. The project was also primarily concerned with perfection of neutron-activation analysis for quantitative identification of impurities in copper.

Neutron activation is an analytical technique in which a sample of material is subjected to neutron bombardment (usually in a nuclear reactor). The atomic nuclei of the sample capture the energized neutrons and become excited and unstable toward emission of beta and gamma rays. The subsequent emission of radioactivity is characteristic of the elements in the sample; when measured, it identifies the composition of the sample.

This activation technique is well suited to study of copper ores because (1) it is sensitive to many of the trace elements of interest; (2) the chemical state of the element is unimportant; (3) mixtures can be analyzed; (4) the analysis requires only small samples and is nondestructive; (5) sample-preparation is simple, and the investment of time per sample is minimal; and (6) chemical procedures are usually unnecessary, so that one can avoid handling of the sample and its contamination with extraneous trace impurities.

Results from the neutron-activation analysis are compared to those by other methods such as emission spectroscopy and spark-source mass spectrometry.

### Reference:

1. Linder, N. F.: Neutron Activation Analysis as Applied to Copper Ores and Artifacts. Argonne National Laboratory, Dec. 1967.

### Notes:

1. This information may interest archeologists, copper smelters, and smelting companies in general.

(continued overleaf)

2. Inquiries concerning this information may be directed to:

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