AXE

DIMENSIONS: 12.5 cm in height

COMPOSITION: Copper with a low arsenic content (0.01 -1% As).

MICROSTRUCTURE

SECTION A: Longitudinal section through the tip of the blade

Photomicrographs

A1 -Interior portion of the blade tip. Large macropores towards the center of the blade (right) remain from the original casting. Metal closer to the axe surface (left) is devoid of pores. Grains throughout the section are recrystallized, equiaxed, and exhibit annealing twins [x50; Etchant: $NH_4OH + H_2O_2$].

A2 -Extreme end of blade tip. Grains are highly distorted and elongated. Most grains are full of strain lines. Pores have undergone compression and are strung out in the direction of metal flow [x50; Etchant: $NH_4OH + H_2O_2$].

A3 -Detail of microstructure of extreme end of blade tip. Note the high density of criss-crossing strain lines within the grains [x100; Etchant: $NH_4OH + H_2O_2$].

SECTION B: Longitudinal section through the butt end of the axe

Photomicrographs

B1 -Extreme end of axe butt. A few grains along one edge contain strain lines. Most grains are recrystallized, equiaxed, and contain annealing twins. Pores are small and spherical [x50; Etchant: $NH_4OH + H_2O_2$].

B2 -Upper edge of axe butt. All grains are recrystallized, equiaxed, and contain annealing twins. A fine network of pores is present throughout the metal [x50; Etchant: $NH_4OH + H_2O_2$].

AXE

INTERPRETATION OF MICROSTRUCTURE

The axe was cast close to its present shape. The large pores that are located towards the interior of the metal (known as center-line porosity) formed as the molten metal shrank upon cooling and solidifying. The more spherical pores may also represent bubbles that formed in the molten metal from escaping gases.

The original cast axe was only slightly cold worked--probably by hammering--in order to refine its shape, and the metal was annealed after having been cold worked. It is impossible to tell how many sequences of cold work, followed by annealing, were employed to achieve the final shape of the axe. Since the pores have remained spherical and undistorted, hammering must have been slight. The metal was left in an annealed condition, as demonstrated by the equiaxed grains with their annealing twins that characterize the microstructure of most of the axe.

Only two very localized areas were cold worked subsequent to the final annealing operation. The extreme cutting edge of the blade tip was heavily cold worked, presumably to harden the metal at the tip. Evidence of this severe cold work is given by (a) the extreme elongation of the grains at the tip as the metal plastically deformed and flowed in the direction of working; and (b) the numerous, criss-crossing strain lines that fill those elongated grains.

A second area that exhibits a minimal amount of cold work is one edge of the butt end of the axe, where some grains contain strain lines, evidence of plastic deformation. This slight cold work could have occurred from some final, local hammering of the butt edge to shape it, or it could have been produced if the butt edge struck a blow against another, harder material. Either action would have deformed the metal sufficiently to produce the strain lines observed.