hand, metastable cordierite ($Mg_2Al_4Si_5O_{18}$), synthesized at high temperature from a melt, has abundant Al–O–Al linkages that are removed as the crystal is annealed[6]. X-ray data on a metastable hexagonal polymorph of anorthite ($CaAl_2Si_2O_8$) suggest that it, too, is disordered. A tentative pattern is suggested here: structures with interstitial cations that are smaller and more highly charged (giving a higher field strength) may have a greater tendency to form Al–O–Al links to enable greater localization of negative charge.

The intriguing report of Klinowski *et al.* in this issue[1] may be the first definitive report of true local Si–Al disorder producing abundant violations of aluminium avoidance in a sodium aluminosilicate mineral with a Si/Al ratio of about 1. The authors also point out the contrast between the disordered, synthetic phase and its ordered natural counterpart. It is likely that the synthetic phase is formed far from equilibrium, and thus is highly metastable. The energetic implications for even more disordered, less stable phases could be significant. Those of us studying glass must be careful when assuming that Lowenstein's rule for equilibrium crystals also applies to their amorphous counterparts. □

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J. Stebbins is in the Department of Geology, Stanford University, Stanford, California 94305, USA.

Archaeology

Getting blood from stone tools

Paul G. Bahn

NEW techniques developed by the Canadian scientist Thomas Loy have led to the discovery of Neanderthal blood on a stone tool from a site in Iraq, and to the accurate identification of the animal species on which other stone tools were used. Extracting blood from stones is likely to be of great importance in terms of new archaeological knowledge, and a massive amount of work remains to be done on the millions of stone tools lying in the museums of the world. These tools may hold the kind of information which early archaeologists could only dream of obtaining.

The archaeological world was both startled and excited in 1983 when Loy, of the British Columbia Provincial Museum, Canada, claimed[1] to have found blood residues surviving on the edges of ancient stone knives. After use of a tool, blood dries and fixes quickly, although some seeps into the surrounding soil when the object lies buried. Providing that the right combination of temperature, moisture and acidity is present, the haemoglobin survives intact, and can therefore be crystallized out and analysed, assuming that the tool is not cleaned too well after excavation. The shape of the crystals of haemoglobin varies between animal species, and provides a means of identifying on which animal a tool was used.

Loy studied 104 tools of chert, basalt and obsidian from open-air sites in coastal British Columbia, with dates from 1,000 to 6,000 years ago, and identified haemoglobin from animals such as moose, caribou, grizzly bear and sea-lion. He also obtained radiocarbon dates from some blood residues using accelerator mass spectrometry, which requires only minute samples for analysis.

An artefact from Strawberry Bluff, a site in northern British Columbia, produced a corrected date of 1,010 ± 90 before present (BP), which matches a date from the charcoal of a nearby hearth (1,060 ± 160 BP). The blood turned out to be that of a snowshoe hare (*Lepus americanus*). A bifacial knife from Toad River Canyon, a site in the same region, had residues of both caribou and human blood, and produced a date of 2,180 ± 160 BP, which fits the style of this tool (the site is now destroyed and was never dated).

Loy has now extended and improved the technique[2]. He finds that blood residues can survive on tools for at least 100,000 years: three tools from Barda Balka, north-east Iraq, had deposits of mammalian (probably ruminant) blood, and this open-air site has been dated geologically to between 75,000 and 125,000 years ago. Other examples have been found on tools of lesser age from Belgium (20,000 BP); Jarmo, Iran (8,000–10,000 BP); and Nevada (6,000 BP) as well as those from northern Canada, indicating that such residues can survive in a wide range of environments. It is therefore possible that they will eventually be found on tools of far greater antiquity.

Loy's original method of extracting and crystallizing the haemoglobin in the residues has now been supplanted by the electrophoretic separation of all blood proteins, a method in which protein molecules are separated by their different mobility and migrations in a gel to which an electric field is applied. The pattern of blood separation is compared with control samples from different animals, and the species can thus be identified. Where the identification points to human blood, Loy uses an immunological testing procedure; of the 25 tools analysed in this way to date, 18 have positive reactions for the presence of human immunoglobin. In one case (a tool from Barda Balka), the blood is almost certainly Neanderthal.

This result by no means necessarily indicates the existence of cannibalism or sacrifice. Every flint-knapper or excavator of sites with stone tools knows only too well how easy it is to slice your finger open on a sharp edge. In more recent cases, however, the blood is directly associated with the cause of death, as in the residue on an arrowhead found in the rib cage of a young female skeleton of about 1,400 years ago. Elsewhere, a burial ritual seems to be involved, as in the bifacial knife found[3] with some dismembered bodies from a mass grave in eastern Canada of the fourteenth century AD.

The possibilities for analysis of human blood residues are enormous, ranging from research on the history of specific diseases to work on genetics and human evolution, and isotope analysis for reconstruction of past environments and diet[4]. Advances have recently been made in the study of use-wear on ancient tools, and of residues on their edges such as fragments of hair, feathers or plants, all of which can help to explain their function. The discovery of blood residues not only pinpoints the species on which the tool was last used, but can also produce an apparently accurate date for that use — a great step forward, as stone tools could previously be dated only by style or by stratigraphic position. □

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Paul G. Bahn is a freelance writer of archaeology at 428 Anlaby Road, Hull HU3 6QP, UK.

100 years ago

SYNTHESIS OF GLUCOSE

ANOTHER important acquisition to our store of knowledge has recently been made. Glucose has been artifically prepared by Drs Emil Fischer and Julius Tafel in the chemical laboratory of the University of Würzburg. This happy achievement has long been looked forward to, and cannot fail to give deep satisfaction in chemical circles all over the world. Not only has the sugar itself been actually prepared, but considerable light has been thrown upon that much-discussed question — the constitution of sugars. A remarkable attribute of this artifical sugar is that it is incapable of rotating a beam of polarized light. In preparing a glucose of the composition $C_6H_{12}O_6$ the probability is that both dextro and laevo are simultaneously formed, and thus neutralize each other, producing a totally inactive mixture.

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