tions not only for the evolution of mating systems and sociality, but also for the management of viable populations of these threatened primates.

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Four climate cycles in Vostok ice core

The Russian–American and French international effort for drilling in ice achieved both a technical and a scientific success by reaching a depth of 3,350 m at the Russian Vostok station (78° S, 106° E; elevation 3,488 m; mean temperature −55 °C). In addition to being the deepest ice core, the Vostok core is now believed to cover the past four glacial–interglacial cycles (~400,000 years), a surprisingly long climate sequence which will be a valuable tool for palaeoclimatologists.

Hole number 5 started from the surface in 1990 and reached 2,755 m at the end of January 1994 (ref. 1). The station had to be closed for the winter because of financial and technical difficulties, but reopened the following summer season. Drilling operations were restarted and continued through the 1995 winter by three Russian drillers (headed by N. Vassiliev). By January 1996, the drilling had reached 3,350 m, but again was stopped because the station had to close for the winter.

The first 2,755-m-deep ice core had already provided the longest undisturbed ice climate record (Fig. 1). Studies of the deuterium (δD; a proxy for temperature), dust and $\delta^{18}O$ records clearly showed that this core covers almost two full climate cycles[1,2] (~240,000 years). The ice was processed during the 1995–96 field season for electrical conductivity measurements (ECM). Apart from volcanic events, the background ECM signal is linked to acid concentration, and therefore depends on the balance between cation and anion concentrations. This changes dramatically between glacial and interglacial times as a result of changes in the intensity in sources of marine and continental aerosols and/or changes in their transport by atmospheric circulation[3–5]. High conductivity (acidity) is observed for the last interglacial ice (marine stage 5.5) as well as for the three warm substages of stage 7, whereas the signal appears lower for stage 6 and cold substages of stage 7. Despite noticeable differences, ECM gives a stratigraphy consistent with that provided by the isotope record.

Below 2,755 m, we observe two long intervals of sustained high electrical conductivity, at 3,073–3,124 m and 3,262–3,298 m depth in the core. We believe that these correspond to interglacial stages 9 and 11, respectively. This is confirmed by deuterium data as well as by preliminary dust measurements, which both fall between Holocene and last interglacial levels. An ice layer at 3,020–3,035 m has a similar 'interglacial' ECM signal but no clear deuterium signature in stable isotopes, possibly because of the insufficient time resolution at this period. Warm marine substages 9.1 and 9.3 may correspond to intervals 3,020–3,035 m and 3,073–3,124 m, respectively. For ice

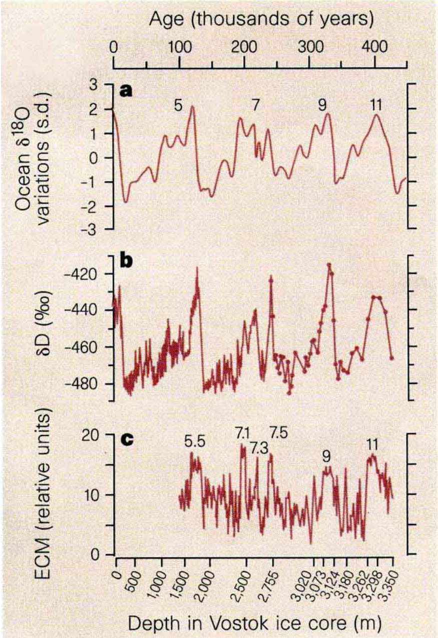

Figure 1 Vostok and marine climate records over the past 400,000 years. **a,** Ocean $\delta^{18}O$ variations (standard deviation units) deduced from foraminifera data from deep-sea cores (SPECMAP stacked record from Imbrie *et al.*[6]). **b,** Vostok δD values (expressed as ‰ with respect to Standard Mean Ocean Water). The continuous deuterium profile down to 2,755 m is from Jouzel *et al.*[1] and from a discontinuous set of samples below this depth. **c,** Vostok ECM signal (3-m running mean and expressed in relative units) for depth below 1,500 m. Numbers indicate marine stages.

deeper than 3,124 m, the ECM fine structure (with patterns also depending on cation and anion concentrations; I. B., manuscript in preparation) suggests that the high dust input of glacial stage 10 started at 3,139 m. This level, dated to 340,000 years in the SPECMAP chronology[6], should mark the boundary between stages 9.3 and 10. The interval 3,139–3,250 m probably corresponds to cold stage 10 and the high, short ECM event around 3,180 m results from a high aerosol concentration. Before warm stage 11 (below 3,298 m), the deep ice close to 3,350 m displays a low ECM signal, low deuterium content and high dust concentrations. This deepest part was thus probably deposited at the end of the previous glacial period (that is, at stage 12).

For a very preliminary age estimate, we assume that the ice layers thin linearly with depth below 2,755 m (240,000 years ago) and adopt an age of 340,000 years at 3,139 m depth. Although simple, this approach appears reasonable: age at 3,030 m (310,000 years) is consistent with stage 9.1; ages at 3,262 and 3,298 m (385,000 and 400,000 years) are more or less in agreement with stage 11, and 426,000 years at 3,350 m is consistent with the end of stage 12.

A wealth of climate-related information will be soon available back to 400,000 years or so ago. The period from 240,000–400,000 years is recorded in about 600 m of ice, which will allow us to study it with high resolution: 1 m of ice would represent 200 years at 2,755 m, 260 at 3,000 m and 450 at 3,300 m. Current measurements include the crystalline texture of the ice, the isotopic composition and concentration of aerosols, chemical constituents and cosmogenic isotopes, as well as the elemental and isotopic composition of the entrapped air bubbles. The last 300 m of ice to be drilled (drilling will be stopped 50 m above the water lake[7]) may have the potential to extend the climate sequence still further back in time, although disturbances of the layers, as seen for the deep ice in the Greenland ice core, are likely to appear.

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Evidence for stone age cranial surgery

In 1996 an exceptionally well preserved skeleton was excavated at the stone age burial site of Ensisheim (Alsace). The cranium of the buried individual shows clear evidence of two trepanations (surgically created holes in the skull). Signs of long-term healing indicate that this type of *intra vitam* surgical intervention was skilfully practised more than 7,000 years ago. Our findings from the Ensisheim skeleton represent the earliest unequivocal evidence of healed trepanations yet discovered.

The Neolithic burial site of Ensisheim is among the best documented necropoles of early agriculturalists in France[1]. Its archaeological context is representative of younger linear pottery (5200–4900 BC) in central Europe. Burial number 44, discovered in September 1996, contained the well-preserved remains of a man who died at roughly 50 years of age. Grave goods assign a date of 5100–4900 BC typologically and a ^{14}C-estimation of the age of the human bones validates the archaeological data (Utrecht ^{14}C laboratory sample UtC-5406: 155±39 radiocarbon years before present, ~5100 BC).

Trepanation is the surgical removal of sections of the cranial vault during life[2]. The skull from burial 44 has two of these surgical openings, both of which show clear evidence of healing (Fig. 1). The anterior opening shows solid and complete osseous restoration of the defect by bony healing. The posterior opening shows only partial healing. Restored surfaces are quite thin in places, probably due to the enormous size of the defect. As a rule, for osseous defects larger than 5 cm in diameter, residual openings are left in modern clinical cases[3,4]. If complications such as haemorrhage, brain damage, wound infection or meningitis do not occur after craniotomy, and if primary bone healing takes place, reactive processes fail to develop and long-term survival is observable[5,6].

Holes in ancient skulls may be caused by infections, tumours, fractures, post-mortem animal activities, damage during disinterment or by selective erosion[2,6]. All of these defects can resemble trepanation openings on superficial investigation. In the present case, diagnosis is unequivocal. Our findings clearly indicate that the individual underwent *intra vitam* surgical treatment twice, either consecutively or simultaneously.

Field studies on trepanation provide valuable insights for reconstructing the motives for such neurosurgery[7]. In native African communities, there are traditionally two motives for trepanations: therapeutic, for head injuries such as fractures; or 'magical'/spiritual therapy, for head (brain) disorders such as persistent headaches, epilepsy, intracranial tumours, and mental disease. Motives inferred for the execution of trepanations in prehistoric times must necessarily remain speculative. In the man from burial 44, we could not find any indications of ailments requiring therapeutic measures, but their existence cannot be ruled out.

Trepanations are among the most fascinating surgical operations in human history executed in both the Old and New Worlds[8,9]. Up to now, claims to cases predating the Late Neolithic age[10,11] have been highly dubious. The case we describe is exceptional for several reasons: it appears to be the oldest healed neurosurgical operation known worldwide, its technical realization testifies to the high craftsmanship and well-founded anatomical knowledge of the surgeon, and the success of the unusual trepanations is established by the long survival of the 'patient'.

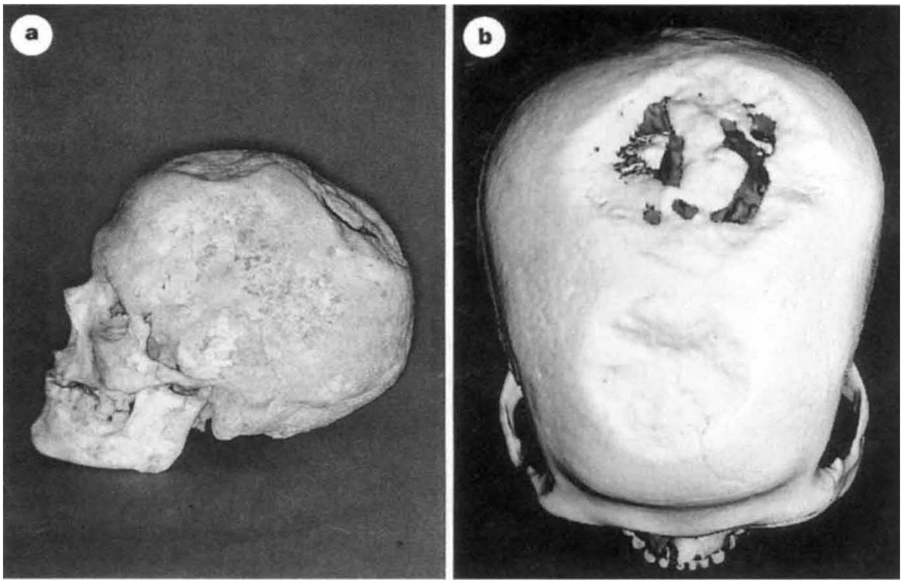

Figure 1 a, Photograph of the cranium, lateral view. **b,** Three-dimensional computed-tomography reconstruction of the cranium, superior view (details of the technical procedures are available on request from the authors). The two trepanations are quite similar in shape. The anterior, smaller trepanation (6.5 × 6.0 cm) is located in the frontal bone, nearly reaching the coronal suture, and extends slightly more to the right side of the cranium. The orifice is closed completely by advanced reactive bone development. The larger, rhombic trepanation (9.5 × 9.0 cm) extends over both parietal bones, with larger portions on the left side of the cranium. Two- and three-dimensional computed-tomography reconstructions of the cranium show complete consolidation at the borders of the trepanation with increased sclerosis.

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