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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.

Figure 1

Vostok and marine climate records over the past 400,000 years. a, Ocean δ18O variations (standard deviation units) deduced from foraminifera data from deep-sea cores (SPECMAP stacked record from Imbrie et al.). b, Vostok δ18O values (expressed as a deviation from Standard Mean Ocean Water). The continuous deuterium profile down to 2,755 m is from Jouzel et al., 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.

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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. 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 14C-estimation of the age of the human bones validates the archaeological data (Utrecht 14C 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. 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. 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.

Holes in ancient skulls may be caused by infections, tumours, fractures, post-mortem animal activities, damage during dismemberment or by selective erosion. 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. 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. Up to now, claims to cases predating the Late Neolithic age 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 realiza-

![Figure 1a](image1)

![Figure 1b](image2)

**Figure 1a,** 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 x 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 x 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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