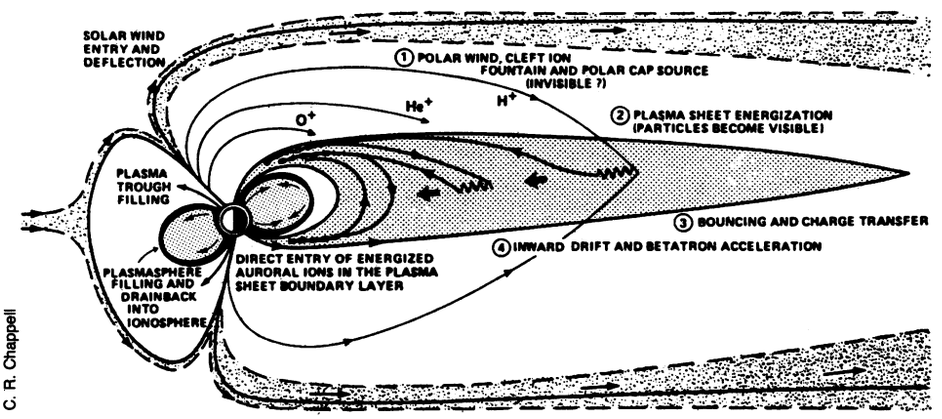


C. R. Chappell

How to fill the magnetosphere. *In this cross section including Earth and its atmosphere (small concentric circles to left), ions spray out of the ionosphere of the upper atmosphere, as indicated by the arrows, to fill various regions of the magnetosphere. The solar wind, which flows from the left, distorts the magnetosphere and contributes ions as well. The relative proportions of ionospheric and solar ions remain to be determined.*

variety of leaky spots around the globe. The particular mechanisms by which electric and magnetic fields can accelerate atmospheric ions vary from place to place, but one or another is operating in the oval auroral zones encircling either magnetic pole, at the polar cusp where the divergence of magnetic field lines opens a cleft in the magnetosphere, and within and equatorward of the auroral ovals where a polar wind of ions flows outward. These flows include the ions of elements ranging from hydrogen to molecular oxygen at energies ranging from 1 to more than 10,000 electron volts. Solar wind ions have energies of about 1000 electron volts and radiation belt ions energies of a million electron volts. The best opportunity to assess the full breadth of these ionospheric flows came with the 1981 launch of the two Dynamics Explorer satellites.

In the latest such study, Chappell and colleagues at Marshall, Thomas Moore and Jack H. Waite, have used the Dynamics Explorer data, ground-based observations, and modeling to estimate the flux of ions from the ionosphere as being in the range of 3.5×10^{26} ions per second. A source of this magnitude "appears to be competitive with even the most optimistic solar wind" sources for filling the magnetosphere, says Chappell. These researchers then used their estimates of the fluxes to each region of the magnetosphere to predict the density of ions that would be there if only the ionosphere were supplying them. The predicted densities are in excellent qualitative agreement with observed densities, Chappell concludes.

If the ionosphere were to suffice as a source of magnetospheric ions, what role would be left in Chappell's scheme for solar ions? Some definitely enter the magnetosphere. If they do so in significant numbers, Chappell says, then perhaps the most reasonable conclusion is that some magnetospheric ions are still escaping detection. He argues that the problem no longer resides in any limitations of the instruments themselves but in the spacecraft carrying them.

It is well known that sunlight as well as the magnetosphere's plasma of ions and electrons tend to charge up spacecraft. The higher the spacecraft's charge, the higher the energy an ion of the same charge needs to approach the spacecraft and be sampled by its instruments. As a result, there can be a dearth of information, claims Chappell, on the composition, energy, and motions of low-energy ions, information essential to identifying their source.

Chappell is well aware that his case for an all-ionospheric source runs counter to the current mood of the space physics community; both solar and ionospheric sources are now seen as important, perhaps equally important when averaged over time and space. Chappell would not disagree too strenuously. "The final answer will probably be somewhere in between," he says. "But you shouldn't put blinders on. You should be open to the possibility that it's all ionospheric. We want to open the discussion up to its broadest possible extent."

■ RICHARD A. KERR

ADDITIONAL READING

C. R. Chappell, "The terrestrial plasma source: A new perspective in solar-terrestrial processes from Dynamics Explorer," *Rev. Geophys.* **26**, 229 (1988).

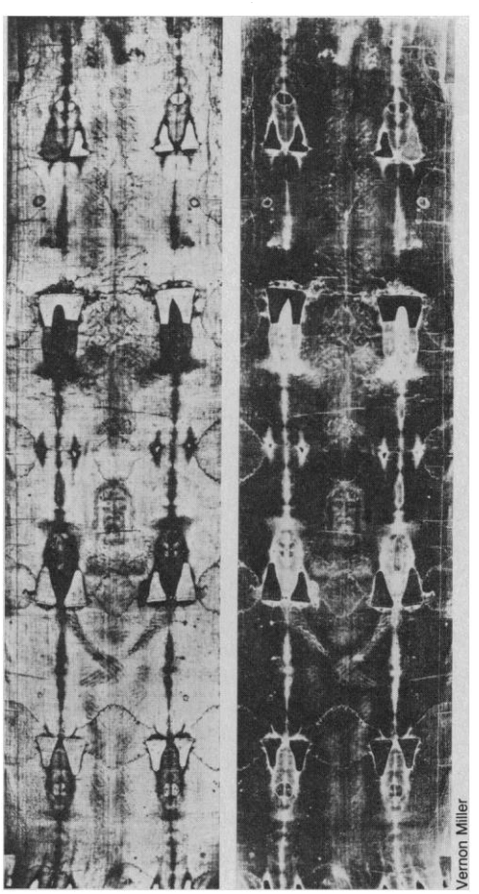
Shroud of Turin Is Medieval

After generations of controversy and months of rumors, the results are now official: the Shroud of Turin, with its haunting, faded image of a crucified man, cannot be the burial cloth of Christ. Carbon-14 dating methods give 95% certainty that the linen of the Shroud dates from between A.D. 1260 and 1390, and virtually 100% certainty that it was made later than A.D. 1200.

The tests were carried out this past spring by independent laboratories in Arizona, Zurich, and Oxford. Each group used the accelerator mass spectrometer technique, which required the sacrifice of only 2 square centimeters of the cloth. The results were announced at a news conference on 13 October by Cardinal Anastasio Ballestrero, the Archbishop of Turin, and by Luigi Gonella, his science adviser. "I see no reason for the Church to put these results in doubt," said Ballestrero, who stressed that the Roman Catholic Church has never claimed that the Shroud was anything but a "representation" of Christ's burial cloth.

Gonella, for his part, was adamant about the use of the word *forgery*. "A forgery is for the specific purpose of deceiving people," he said. "It could be possible, but there is no proof. This could be a medieval icon. We don't even know how it was made."

■ M. MITCHELL WALDROP



Vernon Miller