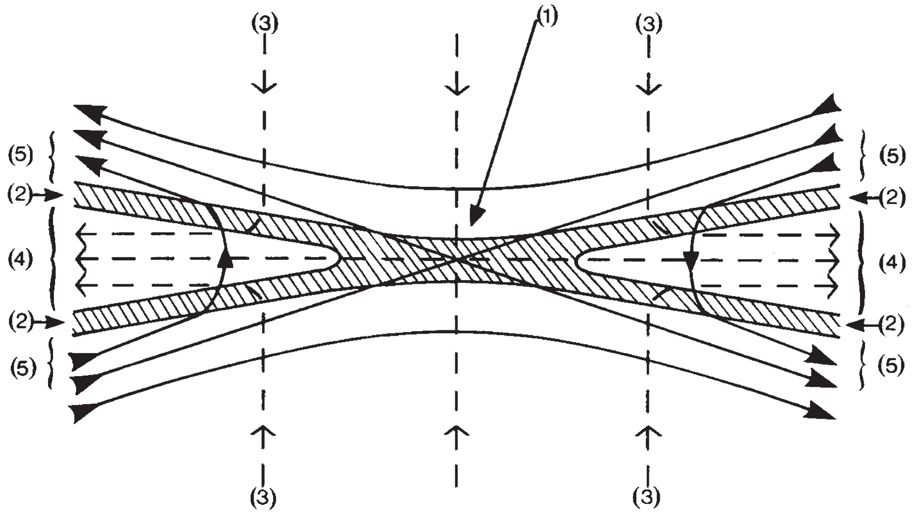
different ways that the field lines in the tail lobes are indeed magnetically 'open', that is they eventually map across the outer surface of the tail into the surrounding solar wind. Changes in plasma bulk parameters, such as density, temperature and velocity, during ISEE-3 traversals of this boundary are reported by Gosling *et al.* [1], who find that well-defined transitions in the magnetic field (sharp changes in field magnitude and direction) are often accompanied by gradual variations in plasma parameters. These observations indicate the presence of direct magnetic flux linkage across the boundary, allowing solar wind plasma a relatively easy access. Abrupt plasma changes also occur, indicating a locally magnetically closed surface.

The second paper deals with the direction of the field in the tail and its dependence on the solar wind field direction, measured simultaneously upstream from the Earth by the IMP-8 spacecraft. Tsurutani *et al.* [2] find that the values of that cross-tail field component that lies approximately parallel to the central current sheet are positively correlated with the corresponding component in the solar wind. In effect, the lobe field (and that in the central current sheet) does not point directly along the tail axis towards or away from the Earth, but is somewhat skewed towards the direction of the solar wind field. This is precisely the result expected for an 'open' tail structure[3], arising from the effects of the magnetic stresses exerted on the plasma by the open field lines.

Equally interesting discoveries have been made about the hot plasma sheet particle population that carries the cross-tail current between the two magnetic lobes of the tail. A previous article in these columns[4] described the initial finding that beyond about 100 Earth radii, the flow of this plasma is directed almost exclusively away from the Earth, indicating that the tail reconnection region usually lies less far from Earth. The appearance of closed field loop 'plasmoids' in the distant tail about 30 min after the onset of magnetically disturbed periods has provided evidence of rapid tail reconnection near the Earth. Confirmation is provided by several papers describing energetic-particle, plasma and magnetic field observations and their relationship[5-7].



The reconnection geometry of Earth's geomagnetic tail suggested by recent ISEE-3 observations. Broken lines are plasma streamlines, solid lines are magnetic field lines, and hatched areas represent regions of high electrical current density. A single current layer or diffusion region (1) at the site of reconnection bifurcates into slow mode shocks (2) in the downstream flow. Plasma flowing from the tail lobes (3) is accelerated across the shocks to form a hot plasma sheet (4) that flows away from the reconnection site on either side. Suprathermal particles, escaping upstream of the shocks, form boundary foreshock regions of streaming particles (5) located on reconnected tail-lobe field lines just outside the plasma sheet. (No attempt has been made to represent the asymmetries that would result from the observed flow of lobe plasma away from the Earth.)

An important subsequent discovery is that the interface between the tail lobe and the plasma sheet often has the character of a slow-mode shock wave[8]. The formation of such shocks resulting from magnetic reconnection was suggested by Petschek[9] over 20 years ago, but ISEE-3 has provided the first evidence for them. The field and plasma structure implied by the observations are shown in the figure. The single current layer separating the tail lobes at the site of reconnection (the 'diffusion region', where the field diffuses through the plasma) bifurcates on either side into two slow shocks standing in the plasma flow. Tail-lobe plasma flowing across the shocks is accelerated away from the reconnection region by the magnetic stresses to form a hot accelerated plasma (the plasma sheet) which is mainly confined beteween the shock waves[10]. However, high-speed ions and electrons are observed to escape upstream of the shocks to form 'boundary layer' or 'foreshock' regions of streaming supra-thermal particles, located on tail-lobe field lines between the surface of reconnected field lines mapping to the diffusion region and the shock waves (see figure)[11,12].

Scarf *et al.*[13] describe a well-defined plasma wave morphology associated with these structures. Electron plasma oscillations of a few kHz are observed in the foreshock region in association with a 'heat flux' formed by field-aligned streaming electrons that have energies above a few hundred eV. These waves therefore probably result form the Landau 'bump-on-tail' instability. A similar association seems to occur in this region between streaming energetic ions (of tens of keV) and the magnetosonic waves reported by Tsurutani and Smith[14]. Within the shock current sheet itself, a spectral peak in electric field noise at frequencies of a few hundred Hz, possibly identifiable as ion acoustic waves, is found[13]. An estimate of particle scattering by these waves suggests that they do not lead to appreciable resistivity; instead the lower hybrid drift instability (at too low a frequency to be measured by ISEE-3) may play an important role[13]. In my view, another important factor determining the structure of the current sheet is likely to be finite ion inertia.

An important question raised by these findings is whether the boundary of the plasma sheet on the earthward side of the tail reconnection region also has the nature of a slow shock. It would be surprising if this were not so in the more distant tail, but the near-Earth regime will be complicated by two factors. First, field line convergence at the Earth mirrors accelerated particles back in to the tail. Second, it is possible that the earthward-streaming plasma observed at the outer surface of the near-Earth plasma sheet predominantly results not so much from local acceleration as from the denser tail-lobe plasma found at somewhat larger distances. A deeper understanding of magnetotail physics will undoubtedly ensue from these and other considerations of the consequences of the ISEE-3 observations. □

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100 Years Ago

THE verdict of the jury who considered the case of the Usworth Colliery explosion is probably the first expression of opinion from a public body of this class that coal-dust and a small percentage of fire-damp can play the part that has hitherto been usually ascribed to fire-damp alone. They found that the explosion was caused by a shot, the fire of which acted upon "*the coal-dust and a small percentage of gas.*". The convenient and time-worn "outburst of gas" theory, which consigned the helpless miner to the vicissitudes of chance and exonerated colliery owners and their agents from all responsibility, seems on the point of giving way before the coal-dust theory.

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