of Frith's results. In the light of our previous discussion of measured solar-proton fluxes, expected shielding due to the Earth's magnetic field, escape of hydrogen from the exosphere, and mixing processes which occur in the winter polar stratosphere, it appears that the coincidence of the integrated influx with the mass of the oceans is entirely fortuitous. However, the importance which is attached to an extra-terrestrial origin for even part of the stratospheric water-vapour means that detailed high-altitude water-vapour measurements, especially in the polar stratosphere, could be of great scientific value.

Finally, one should mention that the oceans account for only 0·025 per cent of the mass of the Earth. Urey[9] indicated that an even greater amount of water was probably held in hydrated silicates in the material which formed the primitive Earth. There is geochemical evidence that the Precambrian atmosphere had much less oxygen than is present on the Earth to-day[10]. It seems more likely that the present oxidized character of the atmosphere has resulted from the dissociation of water and subsequent escape of hydrogen, rather than the ultra-violet dissociation of rocks proposed by de Turville[2]. During the early phases of the Earth's evolution, at which time the speed of rotation was faster and free oxygen in low abundance, the former process probably proceeded quite rapidly.

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The new observations reported by Gringauz and Bridge appear to confirm each other and, if they are correct, the resulting hydrogen accretion-rate will certainly be too small to account for the bulk of terrestrial hydrogen. Moreover, it is now certain that terrestrial deuterium is definitely not due to a slow accretion of solar deuterium. The previously proposed rate of deuterium production at the solar surface ($3{\cdot}3 \times 10^{11}$ atoms cm.$^{-2}$ sec.$^{-1}$) through neutron capture by hydrogen would imply a flux of 2·2-MeV. gamma radiation of $3{\cdot}5 \times 10^{6}$ photons cm.$^{-2}$ sec.$^{-1}$ at the orbit of the Earth, whereas Northrop and Hostetler[1] have set an upper limit of only 0·5 photon cm.$^{-2}$ sec.$^{-1}$ for this flux. It seems inescapable that terrestrial deuterium was produced *in situ* by neutron irradiation of terrestrial hydrogen at an early stage in the evolution of the solar system, as proposed by Fowler *et al.*[2]. In view of these considerations, and the difficulties raised by oxygen supplies, the suggestion I made earlier concerning the origin of the oceans has lost all plausibility and I wish to withdraw it.

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GEOPHYSICS

Orbital Acceleration of Satellites during Geomagnetic Disturbance

Joule heating of the upper atmosphere can explain the fluctuations of orbital acceleration of artificial Earth satellites with geomagnetic disturbance[1,2].

Consider a model thermosphere in which the height (z) rate of change of scale height, H ($= kT/mg$), is constant, that is, $dH/dz = \beta =$ constant (k = Boltzmann's constant, T = temperature, m = molecular weight of gas, g = acceleration due to gravity). Then[3]:

$$p/p_0 = (H/H_0)^{-1/\beta} \tag{1}$$

where p, p_0 are the pressures at height z and at a base level z_0. Assuming m = constant, it follows that:

$$n = n_0(T/T_0)^{-(1+\beta)/\beta}.(g/g_0)^{1/\beta} \tag{2}$$

A crude match of the model to the actual thermosphere is suggested by taking $\beta \approx 0{\cdot}6$ (corresponding to $\frac{dT}{dz} \approx 10°$ K. per km. or a downward flux of about 1 erg cm.$^{-2}$ sec.$^{-1}$). Neglecting the factor $(g/g_0)^{0{\cdot}6}$ over the height-range of present interest (150–650 km.) we have:

$$n \approx n_0(T_0/T)^{\gamma} \tag{3}$$

where $\gamma \approx 2{\cdot}7$. This shows the sensitivity of thermospheric densities to density and temperature at the base-level.

At high magnetic latitudes joule heating peaks at an altitude of about 150 km.[4,5] and falls off with a scale length of about 25–50 km. above and below this height. Those electric currents flowing in the ionosphere to cause geomagnetic variations (Sq) and disturbance (Ds and Dst) (see following communication) modulate the density and temperature at this height and hence at all heights in the thermosphere.

The rate of heating, $Q(Sq)$, attributable to Sq is about 10^{-8} erg cm.$^{-3}$ sec.$^{-1}$. Elsewhere[5] I have shown that such a Q value can modulate the temperature at 150 km. height (0 level) by tens of degrees K., say 50° K. for sake of calculation. Such a change of T_0 will not greatly affect β when $T_0 \approx 500°$ K. originally. There will be a 10 per cent increase in n_0 due to change of scale height at 0 level. It can be seen from equation (3) that the percentage change in n will increase with height until it is about 30 per cent at 650 km. The rate of heating $Q(Ds)$ in low latitudes appears on the average to be about equal to $Q(Sq)$ (see following communication). Thus the average fluctuations of density attributable to joule heating of the ionosphere can amount to about 20 per cent at 150 km. to 60 per cent at 650 km. This compares favourably with variations actually observed[3], namely, ± 20 per cent at 250 km. and ± 50 per cent at 650 km.

At times of severe magnetic disturbance, conditions common to the auroral zones spread to lower latitudes. At these times Q can rise to order 10^{-6} erg cm.^{3} sec.$^{-1}$

(*Continued on page* 75)