particularly in short-term volume control, although it can become important as a fine control mechanism in the longer term. It is interesting that the angiotensin II-stimulated release of aldosterone from adrenal glomerulosa cells[15-17] can be inhibited by physiological amounts of the atrial factor and that avid receptors for the atrial peptide have been found in kidney tubules in smooth muscle of the vasculature and in glomerulosa cells[18].

It is necessary to ask whether the fall of both plasma renin and of vasopression exerts a regulatory or permissive role on the excretion of salt and water. This will not be answered until there have been measurements matching the observed changes in the concentration of atrial factor in the plasma to the different sensitivities in the control of the secretion of these two hormones. There is a long way to go before we can emulate Verney's observation[19], in the allied field of water balance, that a one per cent rise in the osmotic pressure of blood going to the brain is sufficient to produce a maximal antidiuresis. □

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Solid state dynamics

Unsolved problems of creep

from J. Weertman

On page 255 of this issue Doake and Wolff[1] bring new information to a very intriguing, unresolved problem in high temperature creep of crystalline solids. The outcome of their examination of creep flow of ice in polar ice sheets is of importance not only to glaciers but to the deformation of the Earth's mantle and, of course, to the understanding of the creep process itself.

The origin of the problem is the old observation by Harper and Dorn[2] of a creep rate that is proportional to the applied stress (Newtonian creep) in aluminium at relatively low stresses, in conditions such that the creep should be produced by dislocation motion and so is expected to be proportional to a power of the applied stress. This expectation arises from the fact that creep rate is proportional to the product of the dislocation density and the average dislocation velocity. The former quantity, in steady state, is proportional to the stress squared and the latter to the stress. Hence the creep rate is proportional to the cube power of the stress. (Higher powers are also possible[3,4].)

It was easy to dismiss the original Harper-Dorn experiment by claiming that steady-state creep had not been attained. The initial dislocation density in material that shows decelerating creep before steady-state creep is reached is higher than when steady-state conditions prevail. If the creep rate is measured only in a small initial strain region, the dislocation density may be approximately a constant during the course of creep experiments. Hence the creep rate falsely seems to be proportional to stress. Very recently, Soliman and Mohamed[5] have shown experimentally that this applies to the original Harper-Dorn experiment and to more recent experiments that were not extended to large strains. It does not, however, apply to experiments in which Harper-Dorn creep has been measured in metals with large strains[6].

Blacic and I[7] recently offered an explanation of Harper-Dorn creep that has yet to be tested experimentally. We pointed out that the temperature cycling that is inevitable in the usual high-temperature creep tests is sufficient to produce large chemical stresses on the dislocations by periodically altering the value of the equilibrium-point defect density. Hence the dislocation density can be controlled by the chemical stress rather than by the applied mechanical stress. The average dislocation velocity remains proportional to the applied mechanical stress and the creep is Newtonian. This explanation, that Harper-Dorn creep is an artefact of temperature cycling, does not work for Harper-Dorn creep of ice in glaciers and in polar ice sheets, because seasonal temperature fluctuations are effectively removed at depths greater than about ten metres. (This has also been pointed out by Lliboutry and Duval[8].)

Nor, for the same reason, does it work for Newtonian creep in the Earth's mantle. Glacial rebound data and the anomalous motion of satellites orbiting the Earth are very nicely accounted for by analyses of mantle deformation that are based on Newtonian creep for the mantle[9,10]. Moreover, Harper-Dorn creep has been observed by Poirier *et al.*[11,12] in a mineral analogous to one of the presumed major minerals of the lower mantle.

If Harper-Dorn creep is real, and not just a peculiar experimental artefact, life is made easier for modellers of both mantle flow and glaciers. They can use the simpler linear constitutive law in their work. But the rub is that transient creep still cannot be ruled out as the explanation of the evidence for mantle and glacier Harper-Dorn creep. The creep strains that are involved in the analysis of both glacial rebound and anomalous satellite motion are generally quite small. Hence it is still possible to dismiss the application of these results to convection currents in the mantle, where clearly the strains are quite large.

As pointed out by Doake and Wolff[1], the measurements they analysed may also involve non-steady-state creep. The tilt of boreholes gives the creep rate as a function of depth, but the shear stress also increases with depth. To have steady-state creep, the stress must remain constant. Their results can be accounted for either if ice at moderate stresses is indeed Newtonian or if transient creep effects make it appear to be Newtonian although it is not. The same is true of the evidence that indicates Newtonian mantle creep. To help resolve this problem, it would be well worth obtaining the spreading rate of the Ward Hunt Ice Shelf in the Canadian Arctic. This ice shelf is much thinner than the Antarctic shelves considered by Doake and Wolff, and should give another, large creep-strain datum point at a much lower stress level. If ice is Newtonian and if it can be shown that temperature cycles do not account for Harper-Dorn creep in laboratory experiments, the very interesting phenomenon of creep in crystalline solids will remain to be solved. □

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Scanning electron micrograph (× 975) of basalt glass after leaching in NaCl solution at 200°C for 30 days — a model for the stability of nuclear waste glasses. See page 252.