Table 1

Section No.	P3	P46	P48
<i>Globigerinoides sacculifera</i>	24.3° C.	21.2° C.	20.1° C.
<i>Pulleniatina obliquiloculata</i>	21.0	17.9	17.1
<i>Globigerina dubia</i>	19.7	15.0	13.6
<i>Globorotalia menardii</i>	18.7	16.8	—
<i>Globorotalia tumida</i>	15.3	13.6	13.8
Annual rate of accumulation of calcium carbonate	1.00 mgm./cm. ²	0.46 mgm./cm. ²	0.34 mgm./cm. ²
Date of mid-point of section	A.D. 1200	11750 B.C.	12800 B.C.

that the object of his paper was to bring to the attention of microbiologists organic remains, apparently bacterial, preserved in Permian rock salts. Most of the material investigated is from a deep bore-hole at Eskdale. Some of the forms described by Mr. Strong are identical with those in lower Palaeozoic rock salts of Saskatchewan. It is of considerable interest that this organic material has so far been found only in red rock salts, in which the iron is present in minute haematite crystals, or possibly goethite.

The organisms occur as bright red discrete aggregates, which float upwards on dissolving the salt; the most common forms being needles up to $\frac{1}{2}$ mm. in length. They may be sinuous or straight, and are apparently without branches; the threads may form a network, or may be set in a fine membrane of yellowish material. Rarely the threads show a swollen termination, either cylindrical or spindle-shaped with a grooved point. They are highly resistant to heat and acids, and no internal structure has been seen.

Another common form includes fragments of membranous tissue, sometimes apparently structureless, and at other times enclosing a close mesh of threads. A third form is a cyst-like, lozenge-shaped sac of permeable membrane, enclosing liquid. The length is $\frac{1}{2}$ –1 mm. and the width slightly smaller. Twisted threads recalling *Gallionella* occur in the form of ribbons. Mr. Strong suggested that the deposits of haematite found on certain islands in the Persian Gulf may be due to the solution of salt plugs in sea water.

The third paper, on the biogeochemistry of strontium, was by Dr. H. J. H. Bowen, of the Atomic Energy Research Establishment, Harwell. Since the advent of nuclear fission, there has been considerable interest in the biological fate of strontium, as two of its isotopes are among the longer-lived fission products of uranium-235. In particular, strontium-90 constitutes the major hazard, since its half-life is approximately twenty years. The element is readily taken up by plants, and in consequence may be concentrated in the bones of animals feeding on contaminated fodder. Although strontium is widely distributed in Nature, little is known about its behaviour in living organisms, apart from the fact that it tends to follow calcium. Limited knowledge about the biological behaviour of strontium is due in part to the lack of sufficiently sensitive analytical techniques for determining small amounts of the element, as well as to chemical interference of calcium, which in biological material is always present in large amounts. Spectro-

metric determinations are never very precise, and can seldom determine less than 10^{-6} gm./ml. of the element. The method of activation analysis, developed at Harwell, is sufficiently precise to determine 10^{-7} gm./ml. of strontium and is a major advance in the study of the inactive element. The method is used for investigating the occurrence of strontium in rocks, plants, marine organisms and sea water.

In view of the similarity of strontium to calcium, the calcium/strontium ratio is a better index of concentration by an organism than its absolute content. For example, the ratio is 50/1 in sea water, whereas in marine algae (*Laminaria*) it is about 10/1, and in molluscan shells about 200/1. Dr. Bowen concluded from these figures that *Laminaria* prefer strontium to calcium by a factor of five, whereas molluscs reject strontium from their shells by a factor of four. The calcium/strontium ratio in sea water is remarkably small compared with the ratio in most igneous and sedimentary rocks, where it ranges from 100/1 to 1,000/1. Strontium is, therefore, an element which accumulates in the sea, whereas calcium is removed by marine organisms and, to a small extent, by chemical precipitation.

In contrast to its behaviour in marine algae, strontium is neither rejected nor accumulated by the majority of land plants. The calcium/strontium ratio in the plant is generally similar to the available ratio in the soil on which the plant grows. However, in the Bristol district, where there are deposits of celestine, the strontium content of the soil is very high, and plants from this soil reject strontium in favour of calcium. In the Avon Gorge, a locality rich in strontium, one of the rare plants, the Bristol rock cress (*Arabis stricta*), may accumulate strontium. Further work is, however, required, because the low calcium/strontium ratio may in part be due to strontium contamination on its leaves.

J. D. H. WISEMAN

SURFACE RHEOLOGY

ANNUAL CONFERENCE OF THE BRITISH SOCIETY OF RHEOLOGY

THE annual conference of the British Society of Rheology was held in the Washington Singer Laboratories of the University College of the South West, Exeter, during September 22–24. Dr. S. Gregg (University College, Exeter) opened the conference with a paper on the effect of adsorption on the strength of brittle solids. After summarizing the general theory of the subject, he described his recent experimental work, assisted by Dr. D. Dollimore and Dr. A. Desai, on the strength of compacted disks of compressed powders, broken *in vacuo* and in controlled atmospheres. Adsorption isotherms were prepared. The density of elastic energy located between two planes at distance a apart is $\frac{1}{2} \cdot \frac{\sigma^2}{E} \cdot a$,

where σ is the stress and E Young's modulus. Although, in the case of glass at the rupture point the value of $\sigma_{\max}$ is calculated to be 10^{11} dyne cm.⁻², the experimentally measured value is about one-hundredth of this amount. The discrepancy is attributable to the weakening effect of the adsorption of water molecules on the surfaces of incipient cracks. The reduction in surface energy on exposure to vapour, ($\gamma_{\text{vac.}} - \gamma_{\text{vap.}}$), in relation to the amount

adsorbed per gm. of solid is $\frac{RT}{SM} \int_0^p x \, d \ln p$, where S is

the specific surface, p the pressure of adsorption and M the molecular weight. Graphs relating the breaking strength of disks of compacted calcium carbonate, kaolin and boric acid powders, measured under different states of adsorption and desorption, together with derived graphs relating strength and surface energy, etc., were shown.

When benzene vapour replaced that of water in the experiments the strength of the disks remained practically unchanged, although the vapour had been strongly adsorbed with a consequent fall in surface energy. Dr. Gregg explained this anomaly as being due to the relatively large size of the benzene molecule, the ingress of the vapour into the cracks being prevented. In the discussion the meeting supported this view, and considered explanations of other anomalies found under conditions of supersaturation, and the partial absence of hysteresis with boric acid during adsorption and desorption.

In a paper on lubrication by films of solid materials, Miss E. Kay spoke on an investigation at the Royal Aircraft Establishment, Farnborough, made jointly with Mrs. E. Bielak and Dr. E. W. J. Mardles, in which a wide variety of fine powders, including metallic stearates, waxes, polytetrafluoroethylene, molybdenum sulphide, graphite, etc., dry and dispersed in liquid media, were examined under different conditions and between various bearing surfaces. Dry lubrication is often preferable both under the condition of a wide temperature-range, such as that with aircraft, -80°C . to beyond 250°C ., and with light mechanisms of precision when oil seepage and creep, even of 'non-spread' oils and with use of 'epilame' barriers, tend to produce dry bearings and alteration in the inertia of fine moving parts. It was found that with a dry lubricant, although a higher coefficient of friction may be obtainable, the coefficient changes but little over a wide temperature-range. A wide scatter of results obtained with powders under some conditions is attributed to the inclusion of moisture or of oil, to failure of the surface to retain the solid lubricant and to physical changes. Considerable attention is required to find the best method of applying solids for different lubricating purposes.

Members of the meeting then discussed the effect of particle size and shape and the relative merits of dry powders and their use in oil and grease dispersions.

A. F. Latham with Dr. K. G. A. Pankhurst (British Leather Manufacturers Research Association, Egham) spoke on surface viscometry—the tanning of protein monolayers. Insoluble monolayers, spread on a water surface, may exist in a variety of states of aggregation ranging from a rigid two-dimensional 'solid' to an almost perfect surface 'gas'. Mr. Latham described the design and use of a rotational viscometer for measuring the viscous drag of these surface films and distinguishing between Newtonian and non-Newtonian flow.

Protein monolayers exhibit a wide variety of surface rheological properties according to the surface pressure. The changes are reversible and, in the case of serum albumen, can be interpreted by change from the α - to β -keratin pattern. The surface viscosity of collagen is much lower than that of serum albumen due to reduced inter-chain linkage; but, when spread on a tanning material such as mimosa

tannin, the surface viscosity increases by nearly a thousandfold. Mr. Latham described how use is made of the rate of formation of cross-linking to investigate tanning reactions. In reply to queries, he spoke on results obtained with a number of substrates and on the technique used for examining various rheological properties of the monolayers.

In a paper on surface films of poly-di-methyl siloxanes on organic liquid substrates, Dr. W. H. Banks (Printing, Packaging and Allied Trades Research Association, Leatherhead) considered the spreading behaviour of a silicone fluid of average molecular weight 2,000, its surface films having the property of suppressing the foaming of oils and the mottling of paints. The special apparatus developed for the study was described, and graphs were shown relating results obtained for film pressure and film area. Hysteresis effects were observed. Lycopodium was used for observing the rate of spreading on a variety of organic liquids, which was found to be in accord with the relation $l \propto \sqrt{t/\eta}$, l being distance moved, t time in sec. and η the viscosity of the substrate. The movement of the surface films caused a gradient in the substrate, a film of thickness 25 Å. being sufficient to cause motion. In the discussion that followed, members considered possible mechanisms of action of silicone fluid films in suppressing foaming, mottling, evaporation and surface turbulence.

In their paper on the rheological properties of dispersions as criteria of the degree of wetting, Dr. E. W. J. Mardles (Farnborough) and Mr. A. de Waele (Gestetner, Ltd.) first pointed out the difficulties of ascertaining the degree of wetting of a solid surface by a liquid using the Young-Dupré equation modified by Harkins. Contact angles at 'equilibrium' may not exist due to the presence of adsorbed liquid films beyond the periphery of the pool, and the spreading of a liquid over a solid surface can be shown to be non-Newtonian. Although there is some correlation between heats of immersion of powders in various liquids and the rheological properties of their dispersions, numerous exceptions occur due possibly to the fact that the wetting of a surface by a liquid continues over a long period of time. Evidence of this is given by a decrease with time in the viscosity of a freshly made dispersion, by the decrease in the coefficient of friction by oil between bearings during several hours of wetting, and by electrical conductivity measurements which, in the case of a dispersion of carbon black in liquid paraffin (British Pharmacopoeia), continued to change over a period of twelve months. The authors presented results in graphical form indicating the effect of adding wetting-agents on the rheological properties and conductivity of a number of suspensions. Using one powder dispersed in a variety of liquids, or several different powders dispersed singly in the same liquid, the concentration by volume being the same, the rate of aggregation of the particles (indicated by the rheological constants, by the sedimentation-rate and volume, and by conductivity tests) was found to vary considerably, the variations being related to the degree of wetting of the particles by the dispersing media.

The conference included an afternoon visit to the works of the Exeter Brick and Tile Co., Ltd., when Dr. H. H. Macey gave a talk on rheological problems connected with clays and ceramics. At the annual general meeting of the Society, Prof. J. G. Oldroyd was elected president. E. W. J. MARDLES