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Allende Meteorite: Age Determination by Thermoluminescence

by

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An attempt is made to measure the age of Allende meteorite, which fell in Mexico on February 8, 1969, by the thermoluminescence method.

ALLENDE meteorite, which fell in Chihuahua, Mexico, on February 8, 1969, is the largest carbonaceous chondrite ever to have been recovered. According to Clarke *et al.*, who were among the first investigators, at least 1,000 kg of material has been recovered, and estimates of its mass at entry into the atmosphere vary from several tons to >20 tons (R. S. Clarke, jun., E. Jarosewich and B. Mason, unpublished results; R. E. McCrosky, A. Posen, G. Schwartz and A. Tougas, unpublished results; both presented at the fiftieth annual meeting of the American Geophysical Union, 1969). Carbonaceous chondrites, rare as they are among meteorites, are of great importance on account of their organic compounds and peculiar composition. Allende has been classified, as a result of detailed chemical analysis made by Clarke *et al.*, as a type III carbonaceous chondrite as defined by Wiik[1]. Dr Roy S. Clarke, jun., of the Smithsonian Institution, Washington, DC, gave three pieces of this meteorite to one of us (S. A. D.) early in May 1969, and this article reports the work done on the largest of these specimens (Smithsonian catalogue, *NMNH* 3529; weight 34 g). The pieces had been so selected as to contain a fusion crust as well as regions up to a few centimetres away from exposed surfaces. To preserve as much as possible of the thermoluminescence (TL)—both natural and that induced by artificial irradiation by us—the specimens have been kept under refrigeration ($\sim 5°$ C) since receipt.

A prominent feature of the Allende meteorite is the inhomogeneity of its composition. Embedded in the fine grained black matrix (~ 60 volume per cent) are a substantial number of irregularly shaped whitish aggregates (~ 10 per cent) varying in size from ~ 1 mm to several mm in diameter, apart from a steady distribution of grey chondrules (~ 30 per cent) mostly around 1 mm in diameter. Because the TL response of these inclusions may be expected[2] to be quite distinct from that of the matrix, separate investigations were carried out on (i) the aggregates, (ii) the matrix and (iii) homogenized bulk material. The aggregates were mechanically removed from the matrix using a sharp needle and microscopic viewing. The fusion crust was also scraped off the top section by similar means.

The specimen under investigation has been subdivided (Fig. 1) into a number of regions at varying distances from the top surface (fusion crust) in order to observe the variation of natural TL surviving the passage through the atmosphere at these depths. One of the regions immediately below the top has been further subdivided into successive layers B_1, B_2 and B_3, a few mm apart, using a diamond wheel. The material is ground and passed through a sieve to yield a maximum grain diameter of 53 μm (except in the case of separated aggregates and matrix, which were already fine enough and of which, especially the former, only limited amounts were available). Powdered samples of 10 mg are used for each TL readout.

The apparatus and the general procedure we used have been described elsewhere[3] and will not be repeated. In essence, the powder is heated at a uniform rate of 20° C s^{-1} in an inert atmosphere and the TL glow, observed by a photomultiplier, is plotted on an X–Y recorder as a function of temperature. For calibration purposes, control samples from the same region of the sample are subjected to known doses of γ-rays from a large ^{60}Co source and the TL observed in the same way. Areas under the glow curves (in units of A °C mg^{-1}) are then measured between two ranges, 200° to 250° C and 250° to 400° C. If the radiation dose rate in nature before the fall is known, it is then possible by extrapolating the calibration dose-response curve backward to determine, in principle, the (radiation) age of the meteorite. The dose rate from internal radioactivity (α, β and γ) is measured separately, while the cosmic ray dose rate is computed from theoretical considerations.

Fig. 2 shows a typical TL glow curve from the homogenized bulk material from the meteorite; both the natural glow and the enhancement resulting from an artificial γ-ray dose of 440 ± 25 krad superimposed on the natural dose are displayed. Glow curves were also obtained from the aggregates alone and from the matrix alone, but are not shown. Separate glow curves were not obtained from chondrules. The glow area resulting from the fusion crust (to a depth of ~ 1 mm) was found to be negligible ($\sim 2 \times 10^{-9}$ A °C mg^{-1}, that is, down by at least two orders of magnitude in comparison with natural glow from elsewhere, compare Fig. 3), thus confirming the expectation that nearly all TL had been drained from the crust by the heat developed during the fall.

Fig. 3 shows the dose response curve for the homogenized bulk material from two different regions, C and D. The glow areas were measured between 200° to 250° C as well as 250° to 400° C, but because the results were very similar the areas have been combined in the figure. The intercept on the ordinate represents the natural TL. By extrapolating the two curves backwards, an inherent dose of 300 ± 100 krad is found to be present in the meteorite.

It was decided to investigate the reasons for the difference in the glow areas from regions C and D, respectively,

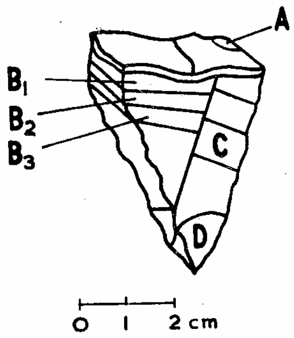

Fig. 1. A sketch of Allende meteorite specimen (*NMNH* 3529, weight 34 g). Sections have been cut with a diamond wheel at varying distances (shown roughly to scale) from the top surface which has a fusion crust to a depth of ~ 1 mm. The cut on the extreme right was made by the Smithsonian Institution, while that on the left is a natural break.

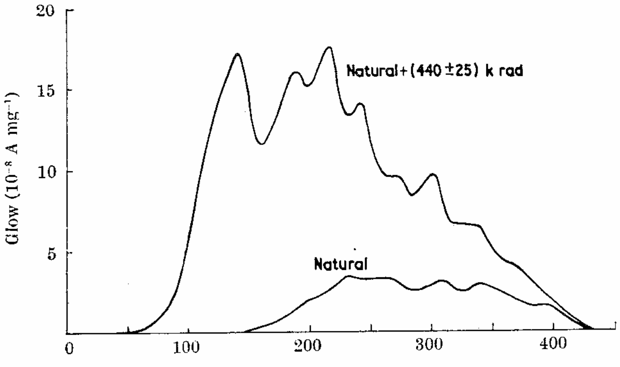

Fig. 2. Typical glow curves from the homogenized bulk material from the meteorite. The lower curve shows the natural glow while the upper curve results from superimposing an artificial γ-ray dose of 440 ± 25 krad on the natural dose. Note the new glow peaks appearing at lower temperatures as a result of irradiation and preserved by refrigerating the sample at 0° to 5° C until the readout. Glow curves were also obtained from separated aggregates and the matrix. TL glow from the fusion crust was negligible.

for they are clearly too far from the fusion crust—being ~ 1·5 cm and 3·5 cm respectively—to be affected by heat; moreover, the farthest region shows the least TL. Aggregates in the meteorite appeared to be prime suspects. To study their behaviour, sections B_1, B_2 and B_3 were irradiated with γ-ray doses of 300, 540 and 800 krad, respectively. The aggregates were then removed from these sections using a sharp needle under a microscope, and their glow curves obtained. The results showed clearly that the aggregates are responsible for most of the glow from the meteorite. As a further test, the glow from matrix material alone was also studied and found to be, on average, one or two orders of magnitude lower than that from the aggregates. Finally, on examining the results of both irradiated and unirradiated aggregates, evidence was found for a wide variation in the amount of glow obtained from different samples. It would therefore seem that only a small percentage of what are collectively called "aggregates" is ultimately responsible for most of the TL glow. Such random inclusions may therefore affect the total glow area obtained from a given section, for example, C or D. The fact, however, that the dose response from the homogenized material is linear in each of the two sections, and extrapolates back to roughly the same inherent dose, makes it possible to draw valid conclusions on age despite the differences in the absolute magnitudes of the observed glow. These wide variations in the absolute magnitude do, however, make a study of the depth gradient of TL very difficult unless complete homogenization can be achieved.

Age Determination

In order to deduce the age of the meteorite from its observed natural TL, it is necessary to know the time rate at which it has accumulated its dose before the fall. Among the factors to consider in this context are the following: (i) its internal natural radioactivity, (ii) the cosmic ray dose and (iii) decay of TL since fall. We shall discuss these separately.

(i) In considering the natural radioactivity, the question of the relative efficiency of the αs, βs and γs in producing TL arises. There is divergence of opinion whether or not they are all equally effective (in terms of equal amounts of deposited energy in rads). According to Aitken *et al.*[4], αs are only 0·3 to 0·05 times as effective in producing TL as βs and γs. The α-activity of the Allende meteorite (homogenized bulk material) has been measured by us. Assuming a Th/U ratio of 3 (the average Th and U contents in most chondrites[5] being 0·04 p.p.m. and 0·014 p.p.m., respectively), and both series taken to be in equilibrium, our measurements lead to the following dose rates from these elements

αs: 66 ± 23; βs: 2·7 ± 0·9; γs: 4 ± 1·4 (all in mrad yr^{-1})

Taking the maximum and minimum α efficiencies for TL production quoted by Aitken *et al.*[4], and combining the three radiations, we obtain total effective dose rates of 27 ± 9 mrad yr^{-1} and 10 ± 3 mrad yr^{-1}, respectively. The contribution of ^{40}K decay to the β and γ dose rate is calculated (using the K content of Allende computed from Clarke *et al.* as 0·024 per cent) to be 2·6 mrad yr^{-1}. (*Note added in proof.* The dose rate resulting from ^{40}K has since been measured by Mrs J. Huxtable as 3·9 mrad yr^{-1}. This value does not significantly affect our conclusions.) Hence the total effective dose rate from natural radioactivity of Allende meteorite varies between ~ 29 and 13 mrad yr^{-1}. A mean effective rate of 21 ± 8 mrad yr^{-1} resulting from internal radioactivity may therefore be assumed for working purposes.

Using the internal radioactivity as the only contributor to TL and assuming no loss of TL during or after the fall, an upper limit can be placed on the age of the meteorite. This is $T_{\text{ir}} = (14·3 \pm 7·3) \times 10^6$ yr.

(ii) Several factors must be considered in calculating the contribution of cosmic rays to the TL observed in a meteorite. The spectrum of primary cosmic rays in interplanetary space extends from ~ 10^9 eV to ~ 10^{19} eV (and spills over on either side). Large local variations are known to occur, over short periods of time, in both the intensity and the spectrum of cosmic rays. It would therefore not be valid to use the data obtained on the dose received by TL powders and so on, flown by rockets and satellites in recent years. As pointed out by DeFelice *et al.*[6], the satellite data often reflect the properties and interactions of solar flare and Van Allen particles rather than those of time averaged cosmic rays in interplanetary space. Moreover, the mechanism of energy deposition in thin layers of powder is quite different in character from that in a massive body.

Recent figures on cosmic rays in interplanetary space are quoted by Ginzburg *et al.*[7] as follows: total particle density, $n_p \sim 1·6 \times 10^{-10}$ particles cm^{-3}; kinetic energy density, $w_p \sim 0·6$ eV cm^{-3}. Local and short term conditions may vary by a factor of 4 to 5, but constancy of average values over millions of years is well established. These values are equivalent (by assuming relativistic

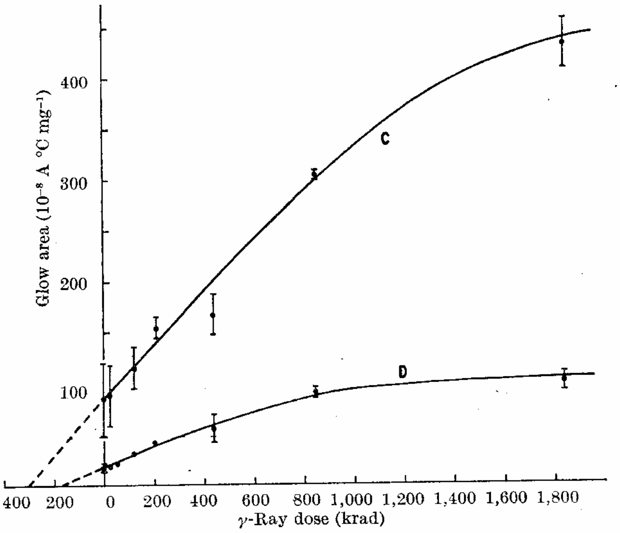

Fig. 3. Dose response curve for the homogenized bulk material from two different regions, C and D (compare Fig. 1). The TL glow areas resulting from each dose have been measured between 200 and 400° C and normalized per mg of sample. The difference between C and D stems from inhomogeneities in the TL response of aggregates (see text). The intercept on the ordinate represents the natural TL on which all the artificial doses have been superimposed. Linear extrapolation of the curves backwards gives estimates of the natural dose in the meteorite.

protons to be the only primary particles) to an average flux of 4·8 particles cm^{-2} s^{-1}, each carrying an energy of 3·7 GeV; that is, to an incident energy of 18 GeV cm^{-2} s^{-1}.

The interaction length of protons of this energy is variously estimated between 100 and 150 g cm^{-2}; say, 125 g cm^{-2}. In Allende meteorite (density = 3·65 g cm^{-3}) this represents an interaction length ~ 35 cm. If all this energy were lost over three interaction lengths (375 g of material), this would represent an average dose of ~ 23 rad yr^{-1}.

It is, however, important to consider the pre-atmospheric size of Allende. According to Clarke *et al.* the total mass of the meteorite on entry into the atmosphere "was evidently several tons". McCrosky *et al.*, on the other hand, basing their estimate on the computed velocity, v, of entry into atmosphere ($11 \leq v \leq 20$ km s^{-1}), find the pre-atmospheric mass $m_0 \geq 2 \times 10^7$ g. Anders[8] tabulates ablation losses of seven iron meteorites between 27 and 99 per cent (with a mean loss ~ 65 per cent). Assuming this figure for a stone meteorite (a questionable assumption), the pre-atmospheric mass of ~ 20 tons may, in fact, not be unreasonable. This corresponds to a radius of ~ 76 cm. If uniform ablation is assumed, so that the post-ablation mass (~ 7 tons) is assumed to have been situated at the core of the pre-atmospheric mass, the overall radius of the core would be ~ 53 cm and the midpoint radius would be ~ 27 cm. Thus the region of interest (containing the material studied by us) must, while in interplanetary space, have been shielded by a median thickness of ~ 50 cm of material (or more, if a smaller post-ablation mass is taken). An approximate calculation shows that, on average, the primary proton of 3·7 GeV would lose ~ 10 per cent of its energy in the core. This yields a figure of ~ 2 rad yr^{-1}. Incidentally, if the data on the erosion rate of stones by interplanetary dust (quoted[8] as 200 g cm^{-2} m.y.$^{-1}$ for spherical chondrites) are taken into account, the core of Allende meteorite would have been completely shielded from cosmic rays except in the past two or three million years.

This calculation for the cosmic ray dose is, of course, an extreme, and highly simplified, picture. In fact, much of the primary particle energy goes into such things as spallation products and generation of secondary particles. The expenditure of energy needed to disintegrate nuclei, create bosons and antibosons and so forth, would greatly reduce the energy left for producing ionization and eventually the electrons and holes responsible for thermoluminescence. It is known from the work of Houtermans[9,10] and his school[11], who use cosmic radiation dose values of ~ 1 to ~ 10 rad yr^{-1}, that this leads to cosmic ray ages of meteorites which are too low by one to two orders of magnitude compared with those obtained from other methods, for example, ^{3}He/^{3}H ratios. The reason for this discrepancy must be that to assume that all cosmic ray energy goes into producing TL is to overestimate the efficiency of the mechanism. Indeed, arguing backwards, one may conclude that the efficiency of cosmic rays to produce TL is only 10 to 1 per cent relative to βs and γs of a few MeV. Assuming all primary energy to be absorbed in the meteorite, our median value of cosmic ray dose (2 rad yr^{-1}) must therefore be reduced by a factor of 10 to 100 if the TL-effective portion of the dose alone is to be considered. This yields a TL effective dose of between 200 and 20 mrad yr^{-1}. If this dose is added to that from internal radioactivity (21 ± 8 mrad yr^{-1}), the age estimate would vary all the way from $T = 1{\cdot}4 \times 10^6$ yr to 7×10^6 yr. This compares with Fireman's estimates for Allende meteorite of $5{\cdot}9 \times 10^6$ yr (^{3}He/^{3}H exposure age) and $4{\cdot}9 \times 10^6$ yr (^{21}Ne/(^{22}N + ^{26}Al) exposure age) (E. L. Fireman, unpublished results, presented at the fiftieth annual general meeting of the American Geophysical Union, 1969).

(iii) Because the meteorite is a very recent fall (February 8, 1969) and has been kept at 5° to 10° C for most of its life (since May 2, 1969), no serious loss of TL is expected in the readout temperature range used by us (200° to 250° C and 250° to 400° C). This conclusion is based on our systematic TL annealing work on tektites[3]. Assuming Randall–Wilkins parameters similar to those for tektites, we would obtain the value of half life at 10° C for a glow peak at 200° C to be > 16 yr.

A final question that must be considered in determining the TL age of a meteorite by measuring its activity is why the internal radioactivity age should be a few times 10^6 yr rather than a few times 10^9 yr. It is commonly assumed that the primordial body or bodies from which the meteorites originate broke up some millions of years (for stony meteorites) to some hundreds of millions of years ago (for iron meteorites), so that the cosmic ray exposure of the interior (now fragmented into meteorites) began only at that time. This suggests that the cataclasm which broke up the parent body must have produced such a high degree of shock throughout the interior (apart from any melting) that it could easily have eliminated any radioactivity-generated TL then in existence. This effect of shock has been experimentally tested by Liener and Geiss[12] and by Houtermans and Liener[13]. The shock at the time of disruption of the parent body must have been colossal in comparison with the laboratory conditions reported by these authors (500 to 800 kbar to eliminate all TL). Thus both the cosmic ray exposure and the radioactivity start building up the TL store from the time of the catastrophic break-up of the parent body a few million or a few tens of millions of years ago. It may be worth mentioning that we have ignored so far any possible loss of TL in the meteorite caused by shock (as distinct from heat) on its entry into the atmosphere. It would thus be interesting to test these effects on, for example, suitable meteorite sized bodies in a space vehicle re-entry experiment.

This article shows that the measurement of thermoluminescence as well as the internal radioactivity of a meteorite can yield an upper limit on its age. This seems to accord with the time that the meteorite parent body broke up (in the case of Allende $\lesssim 14 \pm 7$ m.y. ago): a catastrophic event which apparently eliminated all previous TL. It has also been shown that pre-ablation shielding, and the loss of cosmic ray energy in processes other than those leading to thermoluminescence, are most important factors in determining the contribution that cosmic rays can make to TL observed in meteorites. Study of spallation products in a given meteorite as a function of depth would throw light on the shielding effect, while experiments aimed at determining TL efficiency of particles acclerated by high energy machines should yield results which could then be applied to the age-determination of meteorites.

We thank Dr Roy S. Clarke, jun., and the Smithsonian Institution for kindly providing us with specimens of Allende meteorite; and Miss Joan Thompson and D. W. Zimmerman, University of Oxford, for carrying out the radioactivity measurements for us.

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up sculpture as a career, and now teaches part-time at three art colleges as well as

THE TIMES (22 Sept. 1969)

Science Report

SPACE

Allende meteorite age decided

By Nature-Times News Service

The age of the Allende Meteorite, which fell near Pueblito de Allende, in Chihuahua, Mexico, on February 8 last, has now been estimated by two physicists at Birmingham University. Their report, which appears in the current issue of Nature, is important, not only because it is the first published account of this meteorite, one of the largest ever to have been seen to fall on the earth, but also because the method of age determination should be a useful check on other ways of doing this.

The physicists concerned are Dr. S. A. Durrani and Dr. C. Christodoulides. Their method consists of observing the amount of radiation given out when small samples of the meteorite are heated. The philosophy of the method is that the internal structure of the crystals in the solid material are damaged during the meteorite's journey through space, chiefly because of the impact of atomic particles in cosmic rays.

The energy thus stored in the crystals is released in the form of detectable light when the material is heated. In the past few years this technique has been widely used for estimating the age of archaeological specimens.

The Allende meteorite belongs to the class of carbonacious chondrites that are distinguished by their high content of carbon. In the past two years, indeed, meteorites of this type have been closely studied for traces of chemicals which might indicate that their origin is somehow connected with living processes elsewhere in the gallaxy, but these searches have so far been inconclusive.

Study of the material has shown that the meteorite consists of a black matrix containing most of the carbon in which are embedded a number of small white particles ranging in size from about a millimetre to several millimetres in diameter. In the studies carried out at Birmingham these particles have been used as the chief source of radiation in the age determination. It turns out that the matrix releases only small amounts of energy when heated.

The outer limit for the age of the meteorite, based on the assumption that all the energy released as luminescene of heating can be attributed to internal radioactivity, works out at 14 million years. But taking account of cosmic rays as well, the Birmingham physicists conclude that the age is probably something between one million and seven million years.

The surprising feature of this and other age-determinations of meteorites is that the result is measured in million of years and not thousands of millions of years. Bodies such as the earth and the moon, of course, are roughly 1,000 times older than the ages estimated for the Allende meteorite and similar meteorites from elsewhere. The explanation seems to be that the methods used for determining the ages of meteorites really tell the time when some original parent body, possibly an asteroid, was broken up into smaller pieces by some cataclysm.

Source: Nature, volume 223, page 1219, Sept. 20, 1969.

Appointments in the Forces

Royal Navy

SEPT. 16.—Capt. J. D. Honywill to Fulmar in cmd., Feb. 26; Capt. K. J. Douglas-Morris to Min. of Def. as Dir. Public Relations (Navy), Mar. 4; Capt. J. L. Spanyol to Min. of Def. as Dir. of Naval Manning, Mar. 6; Capt. G. A. Looker, Retired List, Oct. 16; Capt. J. P. K. Harkness to be promoted rear-adm. and Dir. Gen. Naval Manpower to take effect in December; Cmdr. W. H. Hoyle to Victory (to continue to serve in actg. rank of capt.), Aug. 27; Cmdr. S. A. Hammick to Min. of Def. as Naval Attaché, Rome (actg. rank of capt., Oct. 1); Cmdr. J. A. C. Moulson for duty at Cento, Ankara, Jan. 12; Cmdr. M. T. Prest to Londonderry in cmd., Sept. 29; Cmdr. D. A. P. O'Reilly to Min. of Def. with Dir. of Naval Sigs., Mar. 6; Cmdr. G. R. Higgs to Min. of Def. with Dir. of Def. Operational Analysis Estab., Nov. 18; Cmdr. F. J. Robertson to President with B.D.L.S., Canberra, Jan. 12; Cmdr. D. A. H. Borthwick to Phoenix as policy and trials offr., Nov. 21; Cmdr. R. Payne to Min. of Def. on staff of Shape, Nov. 3; Cmdr. H. K. Dean to Min. of Def. on staff of C.I.N.C.A.F.N.O.R.T.H., Mar. 2; Cmdr. E. L. S. Norfolk to Pembroke as supp. offr. to F.O. Medway, Oct. 4; Cmdr. J. S. N. Pryor, Retired List, Nov. 12.

Sept. 19.—Vice-Adml. Sir John Parker, Retired List, Oct. 15; Rear-Adml. W. A. Haynes to Min. of Def. with controller, Sept. 2; Capt. I. G. Raikes to be promoted rear-adml., Jan. 17, to President as naval secy, to take effect in Mar.; capt. W. R. D. Gerard-Pearse to Drake on staff of F.O. Plymouth, Oct. 31 (to serve in rank of commodore w.h.t.a.); Cmdr. J. H. Fiddian-Green to Min. of Def. at Army Staff C., Camberley, Jan. 19; Cmdr. J. L. Lees to Min. of Def. on staff of P.N.O., Govan, Oct. 31; Cdr. R. L. Hewitt to Victory for staff of C.-in-C., Feb. 2; Inst.-Comdr. H. Brierley to St. Angelo as C.-in-C. Service Children's Schools, Malta, Tripoli and Naples, May 20 (actg. rank of inst.capt. w.h.t.a.); Cmdr. A. M. Dennis, Retired List, Nov. 17.

ROYAL MARINES.—Maj. J. P. Synnott, Bem. Retired List, March 7; Maj. E. G. B. Allen, to H.Q., Portsmouth Gp. as D.A.A. & Q.M.G., Feb. 16. Promotions.—Capt. F. C. Townsend, to be maj., March 7.

The Army

BRIGADIERS: D. M. Pontifex, late Inf., apptd. Divl. Brig., H.Q., The Light Div., Sept. 2; H. B. Booth-Mason, late R.C.T., to be chief trnspt. off., H.Q. Army Strat. Cmd., Sept. 26; J. G. Bagnall, late R.A., to be Brig. R.A., H.Q. Army Strat. Cmd., Sept. 22.

COLONELS: R. J. Bond, R.A.E.C., to be S.O.1, Army Eductn., 2, M. of D., Stanmore, Sept. 22; R. M. Carnegie, late R.A.C., apptd. Asst. Dir. Def. Policy (C), M. of D., Sept. 18; Lt.-Col. A. T. Scott, R. Sigs., apptd. col. G.S., Def. Intelligence (Army) M.D. actg. col., Sept. 10; B. A. Stewart, R.H.F., appt. col. A.Q., H.Q. Scotland, actg. col., Sept. 15.

LIEUTENANT-COLONELS: D. H. Briggs, R. Sigs., to be G.S.O.1 (W), Fort Monmouth, U.S., Sept. 21; K. Perkins, R.H.A., to be G.S.O.-1(Ops/SD), H.Q. F.A.R.E.L.F., Sept. 25; J. G. Polley, R.E., to be asst. mil. sec., H.Q. Western Cmd., Sept. 30; H. F. Bott, R.A.P.C., apptd. cmd. paymaster and O.C. Comd. Pay Office, Hongkong, Sept.; D. A. Girvan, R.A.P.C., apptd. paymaster, Regtl. Pay Office, Wrexham, Sept.

Royal Air Force

MINISTRY OF DEFENCE: Gp. Capt. W. E. Martin to dept of C.A.S., Sept. 5; W. Cdr. J. S. W. Bell to dept of C.A.S., Sept. 22; Gp. Capt. R. K. Orrock to dept of A.M.S.O., Sept. 5; W. Cdr. J. R. Stowe to dept of A.M.S.O., Sept. 22.

STRIKE COMMAND: Gp. Capt. D. F. M. Browne to H.Q. for air staff duties, Sept. 19

AIR SUPPORT COMMAND: Gp. Capt. J. E. Cockfield to R.A.F. Fairford to cmd. Sept. 17; W. Cdr. D. G. Croucher to R.A.F. Lyneham as O.C. Ops. wg. with acting rank of Gp. Capt., Sept. 12; W. Cdr. W. I. Macauley to Coningsby as O.C. Admin. wg., Sept. 22.

AIR FORCES GULF: Wg. Cdr. D. J. Rhodes to Air Forces Gulf as S.A.S.O., with actg rank of GP. Capt. Sept. 19.

MISCELLANEOUS: Gp. Capt. K. B. Christensen to H.Q. Shape, as chief elect. systems, Sept. 22; W. Cdr. R. P. Sloss to Cambridge Univ. language research unit as project off. Sept. 11.