tion amplitude would mean that ultimately all virtual dipole moments obtained from rocks older than about 200×10^6 yr should be smaller than the present dipole moment. If the virtual dipole moments from cassiterite represent mean values[2], the discrepancy between them and curves (2) and (3) amounts to a factor of about 7. Krs's suggestion, however, that secular variation had been averaged out in the cassiterite thermoremanent magnetization presumably referred to secular variation of the non-dipole field rather than of the dipole field, in which case the virtual dipole moments from cassiterite are not mean values in the same sense that curves (2) and (3) represent the variation of mean virtual dipole moments. But, even if the cassiterite virtual dipole moments are "instantaneous" values with respect to dipole fluctuations, they still seem to be inconsistent with the pattern of such fluctuation as defined by the boundary curve (4).

In view of the general paucity of data from rocks older than 50×10^6 yr, it is perhaps too soon to say that this inconsistency necessarily implies validity of all virtual dipole moments except those from cassiterite and ignimbrite. Krs[1,2] has shown that both the cassiterite and ignimbrite used by him possessed exceptionally high palaeomagnetic stability. Furthermore, there is still some doubt about whether the apparent increase of mean geomagnetic dipole moment with time represents a real increase or whether it arises merely through gradual decay of rock magnetization over geological time. It is also possible that the natural magnetization in some of the older rocks analysed may have been chemical rather than thermal, in which case the experimental method is not valid[7].

The tentative conclusions that the mean geomagnetic dipole moment has been increasing gradually over the past 400×10^6 yr and that the amplitude of dipole fluctuations has also been increasing are based on the bulk of data currently available. When more data have been obtained these conclusions may have to be revised.

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Effect of the Tunguska Meteor and Sunspots on Radiocarbon in Tree Rings

SEVERAL hypotheses have been advanced to explain the peculiar circumstances associated with the fall of the Tunguska Meteor on June 30, 1908, in Siberia (lat. 60° 55′ N., long. 101° 57′ E.). An exhaustive description of the phenomena is given by Krinov[1]. Especially puzzling is the apparent absence of a meteoric crater, but Krinov[2] does report some recent analyses of soil in the region which show nickeliferous iron and silicate globules.

Cowan *et al.*[3] have discussed the possibility of the phenomena being produced by the annihilation of antimatter in the atmosphere. They have tried to measure the increase in atmospheric carbon-14 which should have been produced by the neutrons generated in the process and consequently recorded in tree rings. Venkatavaradan[4] has discussed the measurements and has suggested that they correlated with the solar activity cycle.

Table 1

Analysis No.	Tree ring date	δ Carbon-13* (per mil)	Δ Carbon-14 † (per mil)
GrN 4886	1894	−26·01	+0·6 ± 1·6
GrN 4904	1898	−25·60	−2·3 ± 1·6
GrN 4887	1901–2	−25·03	−4·2 ± 1·8
GrN 4756	1904	−24·03	−1·5 ± 1·6
GrN 4747	1907	−25·07	−3·7 ± 1·7
GrN 4710	1908	−25·15	−3·8 ± 1·7
GrN 4701	1909	−25·44	−5·6 ± 0·9
GrN 4702	1911	−24·07	−6·9 ± 1·6
GrN 4790	1912	−24·83	−8·7 ± 1·2
Grn 4942	1914	−25·09	−4·0 ± 1·5
Grn 5025	1915–7	−24·83	−7·3 ± 1·6

* Relative deviation in the carbon-13/carbon-12 ratio from the PDB standard sample[5].

† Deviation of carbon-14 activity corrected for isotopic fractionation: $\Delta\,^{14}\mathrm{C} = \delta\,^{14}\mathrm{C} - 2(\delta\,^{13}\mathrm{C} + 25)(1 + \delta\,^{14}\mathrm{C} \times 10^{-3})$ where $\delta\,^{14}\mathrm{C}$ is the deviation of the age corrected activity of the sample.

This communication describes new measurements of radiocarbon in tree rings, with higher accuracy. The results show no significant deviations which could be correlated either with the Tunguska meteor or with the sunspot cycle.

Eleven samples have been analysed. Nine were individual tree rings, and the other two contained two and three rings, respectively. All of them were taken from a section of the same tree, a poplar, *Populus balsamifera* (supplied by S. Westin, of the Norges Tekniske Høgskole, Trondheim, Norway). The tree grew in a windy place outside Trondheim (lat. 63° 25′ N., long. 10° 26′ E.). It was felled during the spring of 1957. For each analysis 30 g of wood was treated successively with diluted acid, alkali and acid. It was then burned to form carbon dioxide, which was purified and used as the counting gas in a proportional counter with a volume of about 8 l. The carbon-13/carbon-12 ratio of the gas was measured and used to correct for variations in isotopic fractionation[5].

The reference activity used was 0·95 of the National Bureau of Standards oxalic acid standard, which was known for the counter with a σ (standard error) of ± 2·2 per mil. The activity of each sample was corrected for age to 1950 using a radiocarbon half life of 5,730 yr. The results are given in the last column of Table 1 and plotted in Fig. 1.

The sloping line in Fig. 1 is the least squares fit to the individual measurements. It shows a decrease in the carbon-14 activity of 0·35 per mil/year, during the time-span covered. This is about twice as large as Fergusson's value[6]. The difference may be caused by a local effect which is at present being investigated.

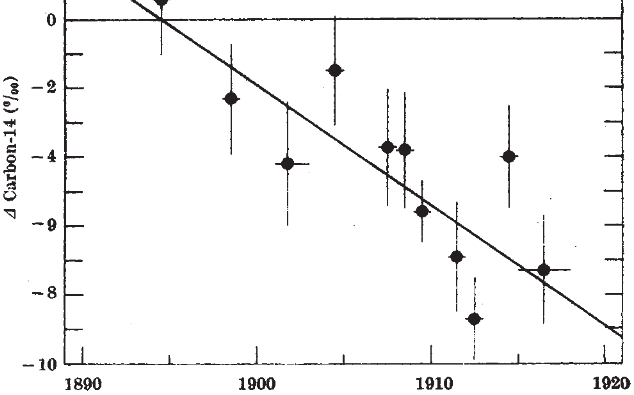

Fig. 1. Deviation of the carbon-14 activity in tree rings. The sloping line is the least squares fit to the points, the slope being caused by industrial dilution and secular variation effects.

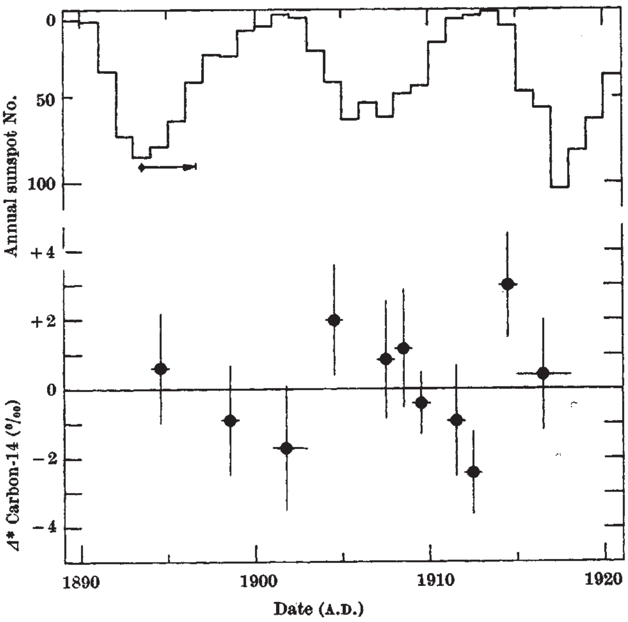

Fig. 2. Deviation of the carbon-14 activity of the tree ring samples relative to the sloping line in Fig. 1; and the annual sunspot number[7] (solar activity). The atmospheric radiocarbon concentration should be proportional to the upper curve, with a maximum allowable phase shift as indicated by the arrow.

In Fig. 2, the same measurements are plotted with reference to the sloping line. Thus the points represent the carbon-14 deviations referred to the average activity of the atmosphere. In the same figure the annual sunspot number[7] is plotted with an inverted ordinate axis, to allow a direct comparison of the carbon-14 deviations with the fluctuations in the production rate of the isotope[8].

From theoretical considerations Cowan *et al.*[3] estimate an increase of 7 per cent for the global atmospheric content of carbon-14 as a consequence of the interaction of a mass of anti-matter large enough to produce the energy release of the Tunguska meteor. Marshall[9] agrees with them, but Gentry[10] calculates only a 2·4 per mil increase. Cowan *et al.* report having measured an increase of about 1 per cent for the carbon-14 concentration in the atmosphere for 1909*, the accuracy of each measurement being ±5 per mil. We do not understand their corrections for isotopic fractionation so it is impossible to give the exact magnitude of the deviation measured by them. According to Gentry, their result does not contradict his estimation, and consequently his hypothesis that the Tunguska meteor consisted of anti-matter.

From our results shown in Figs. 1 and 2, it is concluded that no deviations larger than 3 per mil have been measured, and that any possible deviation around 1909 must be smaller than about 3 per mil (for a degree of certainty of 3σ). Thus if the explosion was caused by annihilation of anti-matter, the first mentioned calculation has not been experimentally verified.

Lingenfelter[8] has calculated the amplitude of the variations in the rate of production of carbon-14 by cosmic ray neutrons, assuming that the galactic component of the cosmic radiation is modulated by the solar activity. The amplitude of the atmospheric carbon-14 variations can be obtained by dividing that amplitude with the attenuation coefficient deduced from Houtermans[11]. A maximum value of about 2 per mil results for the cycles represented in Fig. 2. The maximum phase shift which is permissible is one-quarter of a period, that is, about 3 yr. This shift is indicated by an arrow in Fig. 2. Although there is some suggestion of periodicity in the results, the small amplitude of about 4 per mil does not allow any definite conclusion to be drawn except that the effect must be smaller than this. A much higher accuracy would be needed to detect the expected variations within an individual sunspot cycle with any certainty.

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* Suess measured 0 ± 6 per mil for a tree ring dated 1908 (ref. 12). We think that the peak of the carbon-14 increase should be sought in the tree ring of 1909. Although the Tunguska event happened in 1908, it was already late in the season[13] and it is necessary to add some months delay for atmospheric transport[14].

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Topography and Heat Flow of the Fiji Plateau

The Fiji Plateau is an extensive region at a depth intermediate between continent and ocean basins. Above it rise the islands of Fiji where acidic plutonic rocks occur within an ocean basin in a tectonic setting which can only be compared with the granitic Seychelles Islands in the deep western Indian Ocean. The results of the few seismic refraction lines run on the plateau indicate a variable crust of intermediate thickness[1]. Thus the Fiji Plateau is an unusually interesting and promising region for tectonic studies. In the spring and summer of 1967, the Scripps Institution of Oceanography expedition Nova studied this region. In this preliminary communication we discuss results in topography and heat flow and suggest a relationship between them.

Twenty-five measurements of heat flow were made from R.V. Horizon and three from R.V. Argo during July and August. Nineteen previous measurements taken during the Scripps Institution of Oceanography expeditions Capricorn and Proa are also considered[2,3]. The present measurements were all taken with a long, thin, Bullard-type probe, 2·0 cm in diameter and 2·3 m long, which penetrates the top few metres of the sediment. Three elements, which were sensitive to temperature, spaced 1 m apart enabled us to measure two different temperature gradients in the sediment. A fourth thermistor above the instrument package measured the absolute temperature of the superjacent sea water. Conductivities of the sediment penetrated were determined by the transient needle probe method[4] on cores taken nearby. When such a core was not available, the weighted mean of nearby conductivity values was used. The measured conductivities for the plateau differ very little, so it is unlikely that the assumed values introduce a significant error.

The Fiji Plateau ranges in platform depth from about 1,000 to 1,700 fathoms and west of Fiji the general trend of contours is north to south. The surface is quite irregular