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Flamm and Lingenfelter are right in pointing out that the flux of particles accompanying solar events, as recorded so far by ground-based (or Earth-bound) experiments, are too low to provide adequate source of excitation for the visibility of daytime luminescence of the lunar surface; for night-time events it is adequate. Whether or not this is so at the distance of the Moon (that is, sufficiently far from the terrestrial magnetosphere) and in all parts of the energy spectrum remains, however, yet to be seen. Possibly the primary solar particles act only as a trigger of the lunar events<sup>1</sup>. The electromagnetic spectrum of the Sun contains ample energy for excitation; but its responsibility for transient lunar luminous phenomena seems to be contradicted by the time-lag, from several hours to a few days, indicated by the observation.

The stellar magnitudes assigned to lunar night-time events by early observers listed in Table I lack quantitative meaning; for no one could make photometric measurements at that time; and the definition of stellar magnitude in use to-day goes back only to 1850 (Pogson). Suffice it to say here that one square second of earthlit lunar surface would appear as a star of +13.5 vis. magn.; and the doubling of its brightness by luminescence would reduce it to only +12.7 magn. An area of 10 square seconds (comparable in size to Herschel's "volcanoes") would then appear as a star of 10.2 magn.

The existence of a positive correlation between solar inactivity and lunar events claimed by Flamm and Lingenfelter would—if confirmed—only deepen the problem, but the residual brightness of eclipsed Moon was found by Danjon<sup>2</sup> (1920) also to change abruptly at the time of the minimum (rather than maximum) of solar activity. At present it should be merely noted that both most conspicuous instances on record of transient lunar luminous phenomena (that is, the Greenacre-Barr and Kopal-Rackham flare-ups of October 30–November 2, 1963; and the Herschel flare-up of April 19–20, 1787) occurred at a time when the Sun was strongly disturbed. No flare observations are available, to be sure, for 1787; but the fact that the Sun must have been greatly disturbed

is attested by the visibility, on both days, of polar aurorae as far south as Padua, Italy<sup>3</sup>.

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## GEOLOGY

### Carbon Isotope Composition of Individual Hydrocarbons from Italian Natural Gases

SINCE the fundamental paper by Craig<sup>1</sup> on the geochemistry of the stable carbon isotopes, much work has been done on the determination of carbon isotope distribution in different materials.

It was found<sup>1,2</sup> that the <sup>13</sup>C/<sup>12</sup>C ratio of methanes from natural gases ranges from –10.4 per mil to –84.4 per mil in δ units. (δ Carbon-13 is determined as follows:

$$\delta^{13}\text{C} = \left[ \frac{(^{13}\text{C}/^{12}\text{C}) \text{ sample}}{(^{13}\text{C}/^{12}\text{C}) \text{ standard}} - 1 \right] \times 1,000$$

Results are referred to the PDB standard (ref. 1).) This range of variation is the widest observed within a single class of carbonaceous materials.

Silverman<sup>3</sup> has recently reported the <sup>13</sup>C/<sup>12</sup>C ratios of individual light hydrocarbons separated from petroleum by fractional distillation. He showed that ethane and propane are about 11 and 13 per mil isotopically heavier than the associated methane. Apart from these data, referred to a single crude oil, <sup>13</sup>C/<sup>12</sup>C ratios relative to ethane, propane and higher hydrocarbons from natural gases are hitherto missing from the literature, in spite of their obvious geochemical importance.

We have developed an experimental technique, based essentially on gas chromatography, which enables the quantitative separation of individual carbon compounds from natural gases. Each hydrocarbon is converted to carbon dioxide, which is then analysed for the <sup>13</sup>C/<sup>12</sup>C ratio using a mass spectrometer equipped with double collector. Reproducible results are thus obtained, with an overall accuracy of ±0.3 per mil. This technique was applied to the examination of natural gases from nine producing fields, located in southern Italy and Sicily. The chemical composition of such gases was also determined by gas chromatography.

The <sup>13</sup>C/<sup>12</sup>C ratio of methane ranges from –37.8 to –71.5 δ units in a total of 52 samples analysed. It was found that the carbon-13 content of methane decreases with increasing molar ratio  $\frac{\text{methane}}{\text{total hydrocarbons}}$  in the gases.

This trend (Fig. 1) is exhibited by all the samples examined, which were collected from different Italian gas fields.

As expected, ethane, propane and butane<sup>4</sup> hydrocarbons are isotopically heavier than the associated methane. The results reported in Table 1 indicate that the ranges of δ carbon-13 for such hydrocarbons are much narrower than that for methane.

The isotopically lightest Italian methanes fall in the same δ carbon-13 range as other methanes of alleged bacterial origin<sup>2,4</sup>. Their δ carbon-13 values indicate a probable depletion in carbon-13 of approximately 40–50 per mil with respect to the original organic matter.

The isotopically heaviest, among the Italian methanes analysed, are associated with relatively large amounts of ethane, propane and higher hydrocarbons. These heavier methanes indicate probable depletions not greater than 20 per mil, in agreement with the results obtained by Silverman<sup>3</sup> for a methane allegedly produced in the 'maturation' of petroleum.

Therefore, the trend of Fig. 1 could be explained by assuming that each gas results from the admixture of an