at unexpected depths and in unexpected circumstances.

Sweet meteorites A popular hypothesis is that amino acids and other organic compounds essential to the origin of life on Earth were delivered to the planet by asteroids and comets. Circumstantial evidence for this comes from the fact that carbonaceous chondrites such as the Murchison and Murray meteorites have been found to contain some of the organic compounds required. But not all. Missing from the count so far have been polyhydroxylated compounds (polyols) such as sugars, sugar alcohols and sugar acids, which are components of nucleic acids (RNA, DNA) and cell membranes and also act as energy sources. These have now been found by Cooper and others (*Nature*, v.414, p.879, 2001) in both of the meteorites named above (Fig. 4) and in quantities comparable to those of amino acids, thus strengthening the 'life from space' scenario. So where did the sugars come from? Cooper and his colleagues conclude that the most likely mechanism is the photolysis of small, simple molecules (CO, NH_3, H_2O, etc.) in the solar nebula – in other words, the formation of more complex molecules under the influence of radiation (starlight etc.). The presumption here, of course, is that the molecules could then survive the transformation of the nebula into the solar system. Alternatively, the large molecules now observed might have formed on the meteorites' parent bodies (asteroids) by formose reactions in which formaldehyde (relatively abundant in interstellar space) in aqueous solution condenses to form hydroxylated compounds. The sugars could also, of course, be terrestrial contaminants, but there is evidence against that: Cooper and his colleagues show that the $^{13}C/^{12}C$ and $^{2}H/^{1}H$ ratios in the sugars are relatively high, reflecting the fact that extraterrestrial organic material (e.g. amino acids) is enriched in the heavier isotopes (^{13}C and ^{2}H) as compared with similar terrestrial materials. In summary, then, it would appear that the early Earth had brought to it almost everything needed to create life.

Is CO_2 the whole story? The link between carbon dioxide in the atmosphere and the Earth's temperature has been widely acknowledged and forms the basis of predictions of future global warming. The correlation appears to be tight for the past four Pleistocene glacial–interglacial cycles and, with a few possible exceptions, to apply generally to the whole of the Phanerozoic. Royer and others (*Science*, v.292, p.2310, 2001) now show, however, that the relationship may not be

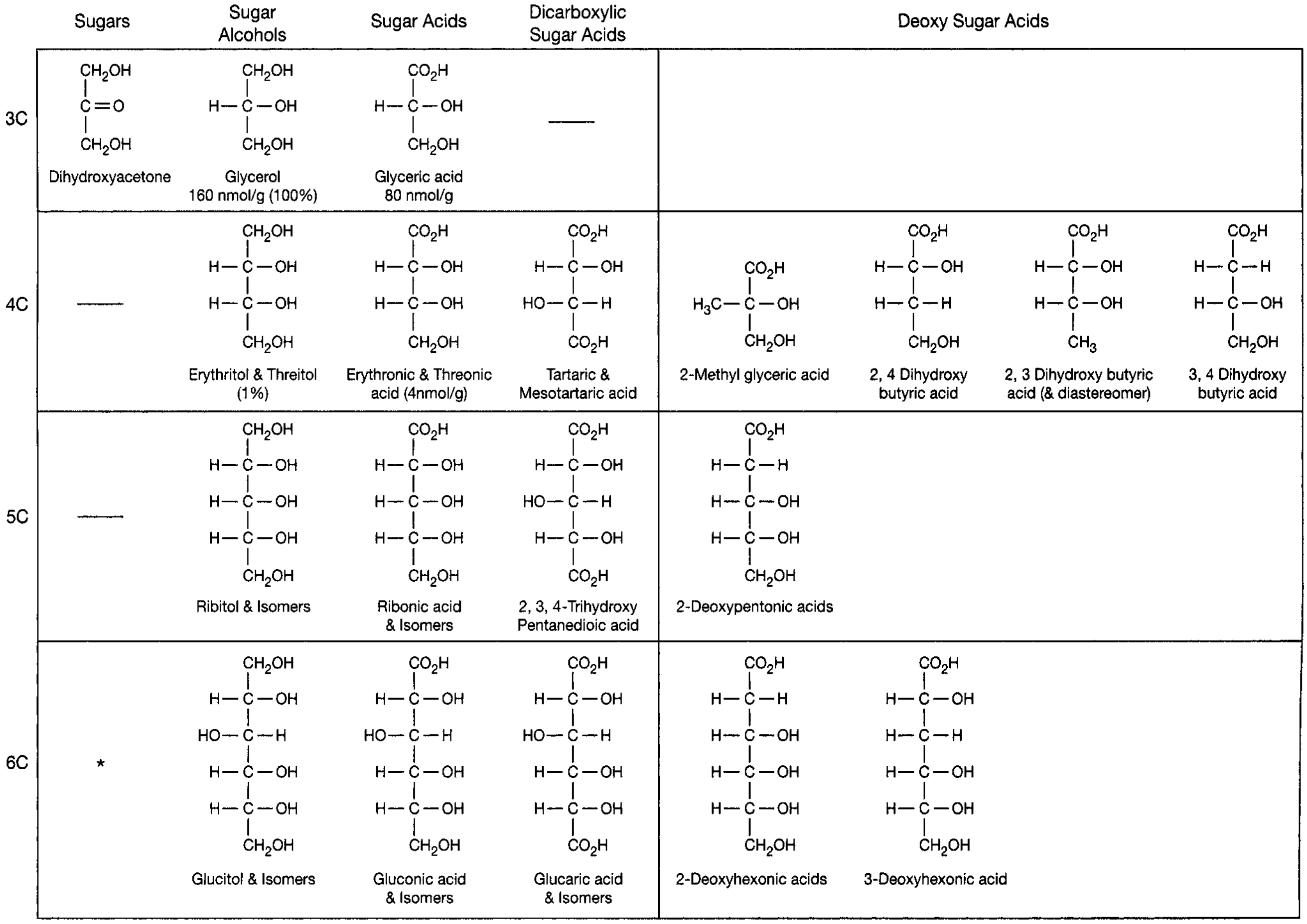

Fig. 4. Polyols detected in the Murchison and Murray meteorites. Chemically, polyols are compounds that have hydroxyl (OH) groups attached to carbon centres. Reproduced, with permission of Macmillan Magazines, from *Nature*, v.414, p.879, 2001.

as simple or proven as previously supposed. They have used the known inverse relationship between the partial pressure of CO$_2$ in the atmosphere and leaf stromatal index in *Ginkgo biloba* and *Metasequoia glyptostroboides* to determine CO$_2$ concentration for the periods 60–53 million years ago (mid-to-late Palaeocene to early Eocene) and 19–15 million years ago (Miocene), finding that, with the exception of a single high value near the Palaeocene–Eocene boundary, CO$_2$ has remained between 300 and 450 parts per million by volume across the whole of those time ranges. Translating this into temperature terms means that, again over the periods considered, the temperature of the Earth should have remained within 1.5 °C of its pre-industrial level. However, other methods (e.g. oxygen-isotope analysis) have demonstrated temperatures of 3–4 °C higher at least once within the stated intervals. 'These results suggest that factors in addition to CO$_2$ are required to explain these past intervals of global warmth', a statement which, if confirmed, could create some havoc in climate-change studies.

Mull ages constricted Most of the Isle of Mull comprises one of the Tertiary igneous centres that go to make the British Tertiary Igneous Province (BTIP) (Fig. 5); the island consists of the products of fissure eruptions, central volcanoes and dyke formation. These rocks demonstrate several periods of reversed (R) and normal (N) magnetism – at least an R–N–R sequence and possibly R–N–R–N–R, although this expanded version may simply be the result of remagnetization. Whatever the precise detail, however, it would appear that at least three magnetic intervals are being sampled by Mull rocks (technically, these are Chrons 26r, 26n and 25r). Enter now Chambers and Pringle (*Earth & Planetary Science Letters*, v.193, p.333, 2001). Their new, accurate ^{40}Ar/^{39}Ar dating of Mull rocks reveals that all lie within a period of 2.52 ± 0.36 million years within reversed Chron 26r (60.92–57.91 million years). So how therefore can some of the rocks have normal polarity? There are two basic possibilities. First, the rocks now seen to have N polarity could be R rocks that were remagnetized in a normal field at a later date. However, cross-cutting relationships imply that no such remagnetization has taken place, and there is no indication of secondary magnetization except in a few instances in which it can easily be removed to reveal the primary. The other possibility is that within Chron 26r there are very short polarity flips (less than 30 000 years) that are too brief to be recognized as chrons but may instead be regarded as cryptochrons or, where confirmed in a magnetostratigraphic study, subchrons. Seven cryptochrons have previously been postulated within Chron 26r; and so Chambers and Pringle now suggest that Mull provides support for upgrading at least two of them to subchron status. There is a clear implication here that the Mull volcanics erupted rapidly enough to sample at least a few of the supposed short polarity intervals within Chron 26r.

Lunar thoughts The hypothesis (the Giant Impact Hypothesis) now widely accepted for the origin of the Moon – that is, the one most, but not entirely, consistent with geophysical and geochemical data – is that it formed from the debris produced in a collision between the proto-Earth and a Mars-sized impactor. If

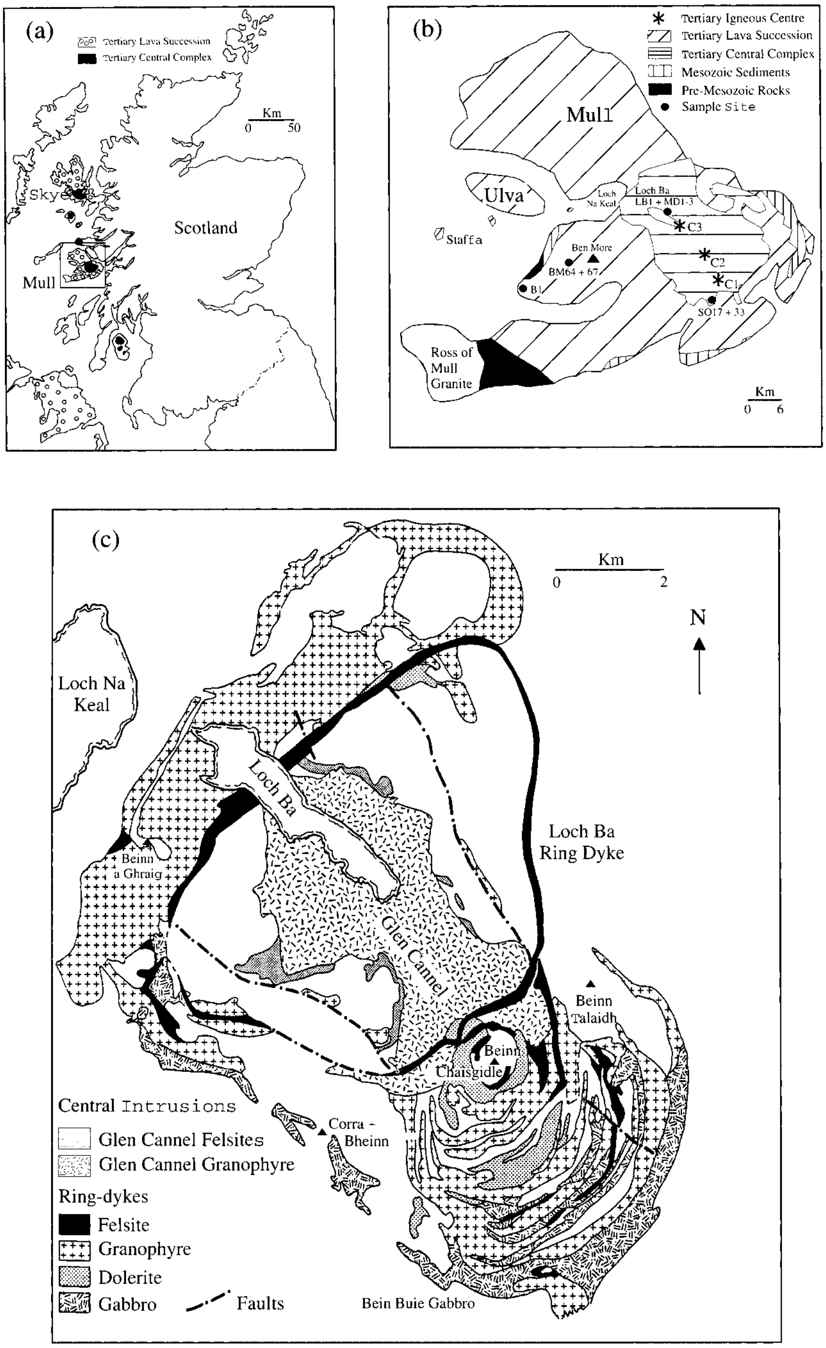
Fig. 5. The Isle of Mull in its geographical context and in the context of the British Tertiary Igneous Province (a), showing its simplified geology (b) and its central complex in more detail (c). Reproduced, with permission of Elsevier Science, from *Earth & Planetary Science Letters*, v.193, p.333, 2001.