this reason and for the fact that his enthusiasm for symmetry physics is one of the expected pleasures of such occasions.

Non-compact groups are the mathematically opulent approach to elementary particles. A more mathematically economical, if physically rather opaque, line of attack is afforded by the use of quark models. Indeed, so economical is this latter approach that it has been noticeably successful in getting many of the $SU(6)$ results without actually assuming $SU(6)$. An investigation of this was reported by Lipkin. Characteristically he finds an interesting new sub-group as the cause.

An elusive particle (if it exists at all) is the magnetic monopole suggested by Dirac in 1931. As he pointed out, it is theoretically desirable since it leads to the otherwise unexplained quantization of electric charge. Schwinger gave a new account of the theory which leads to a different, more restrictive, quantization condition.

The final arbiters of all symmetry schemes are the experimentalists, whose findings can sometimes confirm and often destroy a theoretically elegant possibility. Excellent surveys of the present situation were given by Samios and Frisch. However, occasionally the theorists can get their revenge. Another experimentalist gave a talk on an experiment which he was planning, but a very quick-witted theorist pointed out in a spontaneous comment that the effect sought was identical with, and thus not capable of being disentangled from, another interaction also present. As someone else pointed out, the saving as a result of this observation more than paid for the whole Conference.

J. C. Polkinghorne

EARTHING OF ELECTRICAL SYSTEMS

THE safety and integrity of electrical power supply systems are almost universally dependent on some form of earthing which aims at limiting, under fault conditions, the potential difference between the general body of earth and certain parts of the system. The British Standards Institution has recently published a Code of Practice (*CP* 1013: 1965—*Earthing*) dealing with the subject*.

System earthing, as distinct from the earthing of electrical apparatus, began in the 1890's when the supply was utilized almost wholly for lighting and the need for equipment earthing on consumers' premises was relatively slight. Practice in the matter of earthing consumers' installations developed relatively slowly. While there is no mention of earthing in the first edition of the Institution of Electrical Engineer's *Wiring Regulations* issued in 1885, the third edition of 1897 recommends the earthing of the frames of dynamos and motors and of transformers. The eighth edition published in 1924 contains a substantial section dealing with consumers' installations and mentioning the provision of earth terminals.

Although the safety of electrical installations is a subject which has received much attention in recent years, it is probably not generally sufficiently realized that satisfactory protection by means of simple earthing, together with fuses or circuit breakers, becomes progressively more difficult of achievement as the load taken by the consumer increases.

While, in general, the question of how an electrical system shall be earthed is governed by legislation, the regulations are so worded as to permit any type of earthing provided that it is as safe as is practicable and that it is unlikely to interfere with telecommunication.

The new code of practice deals comprehensively with general considerations and with specific practices relating to the earthing of supply systems and of consumers' installations. There are six main sections, two of which, entitled "General" and "Design Considerations", deal with principles and practice concerning power stations, transmission and distribution systems, consumers' premises, traction and lightning protection. Sections 3, 4 and 5 deal respectively with the temporary safety earthing of high-voltage apparatus or mains, inspection and testing and maintenance. Section 6, which completes the work and is entitled "Miscellaneous", is concerned mainly with a number of specific legislative provisions.

Opening with a statement of scope, followed by a list of definitions, the subject is developed clearly and concisely and with an adequate amount of explanatory material. The Code constitutes an admirably comprehensive guide to earthing practice which will be a work of day-to-day reference for supply engineers, electrical contractors, maintenance engineers and, indeed, for all who have responsibility for electrical installations.

James Greig

* The Council for Codes of Practice, British Standards Institution. British Standard Code of Practice, *CP* 1013: 1965—*Earthing*. Pp. 129. (London: British Standards Institution.) 30*s*. net.

VOLCANOLOGY RESEARCH IN NEW ZEALAND

IN 1963, the Royal Society of New Zealand and the New Zealand Geological Survey (Department of Scientific and Industrial Research) invited the International Association of Volcanology to hold its 1965 symposium in New Zealand, to mark the centenary of the New Zealand Geological Survey. This symposium, held during November 22–December 3 at Auckland, Rotorua, Taupo and Wellington, was attended by more than one hundred delegates from twenty-three countries. The two main subjects were acid volcanism (including ignimbrites) and geothermal resources.

The problem of the genesis of acid volcanic rocks is particularly acute in an area such as the central volcanic zone of the North Island of New Zealand, where the volume of these highly silicic rocks greatly exceeds that of basic and intermediate types, and where individual eruptive units of acid rock are of such enormous volume. The problem hinges on whether this acid magma was produced by the large-scale fusion of crustal material or is a fractionation product of basic magma, itself generated originally within the upper mantle. A further possibility is that the acid magma may even come directly from the mantle.

In New Zealand, the basement which is believed to underlie the volcanic rocks includes a great thickness of Mesozoic to Tertiary greywackes. The chemical composition of these greywackes is such that their partial fusion could produce a melt similar in composition to the observed acid volcanic rocks. This origin is at present favoured by New Zealand geologists; basic and intermediate volcanic material is not sufficiently abundant to be quantitatively acceptable as a parental magma. Geochemical studies which have a bearing on this problem were discussed during the symposium from other circum-Pacific areas, and it was shown how the $^{87}Sr/^{86}Sr$ and $^{18}O/^{16}O$ ratios supported the concept of crustal fusion for the origin of certain extensive acid volcanic accumulations in Guatemala.

It is now known that in volcanic fields such as the central zone of New Zealand, where acid volcanic rocks are present in enormous bulk, a high proportion of the acid material was ejected in fragmental condition by great explosive eruptions. The resulting pyroclastic sheets have a total volume in the Taupo–Rotorua district of New Zealand of the order of 20,000 km³. Particularly noteworthy are the deposits called ignimbrite ('shower-of-fire rock') by the New Zealand geologist, Marshall, in 1935. These deposits are the products of glowing cloud-type eruptions several orders of magnitude greater than has ever been observed in historic eruptions. Often the disrupted particles of magma were still so hot when they came to rest, even at a distance of several tens of kilometres from the vent, as to weld together. Similar deposits have since been found to be widespread in many parts of the world, and the term 'ignimbrite' is now internationally used (although its usage has been varyingly interpreted).

Outstanding contributions to the understanding of the nature and origin of ignimbrites have in recent years come from Japan, New Zealand and the United States, and the recent findings were discussed at the symposium. The relationship of many of these ignimbrites to large collapse calderas, about which they are distributed, is particularly striking; the formation of these calderas seems to be consequent on the rapid emission of huge quantities of fragmented rhyolitic magma.

The central volcanic zone of New Zealand, wherein virtually all the active volcanoes lie, includes, at either end, large andesitic volcanoes—Ruapehu, Ngauruhoe, Tongariro and White Island—which are quite frequently in eruption, although they seldom produce large volumes of new rock. In contrast, the central part of the zone, which includes Lakes Taupo and Rotorua, is characterized by occasional rhyolitic eruptions of extreme magnitude, and the geological record indicates that such eruptions recur at intervals of the order of several thousand years. In this connexion, the problem of the definition of 'active volcano' is particularly pertinent; although the last great eruption was nearly 2,000 years ago, the Taupo–Rotorua area must be regarded as one of high volcanic potential.

To offset the volcanic risk, New Zealand is fortunate in having geothermal fields of great economic value in the central volcanic zone. Since 1952 a power station has been producing more than 100 MW of electrical power from natural steam tapped by boreholes at Wairakei. Drilling programmes in other parts of the zone are at present investigating the further exploitation of this natural asset. Scientific papers presented during the symposium discussed such problems as the economic extraction of the geothermal energy, and theoretical aspects, such as the manner of transfer of heat within a geothermal system. Data were presented from geothermal fields in Iceland, Italy, Japan and the United States as well as from New Zealand.

New Zealand, a leader in the field of geothermal power, was among the first to take steps in the harnessing of the great energy output of volcanoes. Many nations are now following this lead.

I. G. GASS
G. P. L. WALKER

RESONANT SPIN STATES IN THE SOLAR SYSTEM

By PETER GOLDREICH and STANTON J. PEALE

Department of Astronomy and Institute of Geophysics and Planetary Physics, University of California, Los Angeles

TWO explanations have recently been proposed to account for non-synchronous rotation of Mercury[1]. In the first, Peale and Gold[2] showed that the vanishing of the time-averaged tidal torque on Mercury would imply a rotation rate which is intermediate between the planet's instantaneous orbital angular velocity at perihelion and its mean orbital angular velocity. The asymptotic spin angular velocity is determined by the amplitude and frequency dependence of the planet's 'Q' ($1/Q$ is the specific dissipation function[3]). For some reasonable Q's the final spin rate is near the observed 59 days. More recently, Colombo[4] has proposed that the rotation period of Mercury may be precisely 2/3 of its orbital period of 58·65 days. He suggested that this commensurate rotation rate might be stable if the figure of Mercury possessed a sufficiently large permanent deformation from axial symmetry with the long axis oriented toward the Sun at perihelion. Our investigation of such commensurate spin rates indicates that Mercury may indeed have a stable spin velocity which is 3/2 the orbital angular velocity but in one sense almost despite its permanent deformation rather than because of it.

We consider a planet the spin axis of which is normal to its orbital plane. The principal moments of inertia of the planet are denoted by A, B, and C; C being the moment about the spin axis, and B and A being the larger and smaller of the moments in the equatorial plane. The planet moves in an orbit with semi-major axis a, eccentricity e and instantaneous radius r. In Fig. 1 we illustrate the angles we shall use. Line IF is fixed in inertial space, whereas line PS is the planet–Sun centre line. The angle between the long axis of the planet and the centre line is Ψ, f is the true anomaly and θ gives the angular position of the long axis relative to the inertial line IF. In the absence of tidal torques the equation of motion for θ is (ref. 5):

$$C\ddot{\theta} + \frac{3}{2}(B-A)\frac{GM}{r^3}\sin 2\Psi = 0 \quad (1)$$

where G is the gravitational constant and M is the mass of the Sun. From Fig. 1 we find $\theta = f + \Psi$. Suppose we wish to determine the stability of a planetary spin angular velocity near $pn/2$, where n is the mean motion of the planet and p is any integer. Defining a new angle $\gamma = \theta$

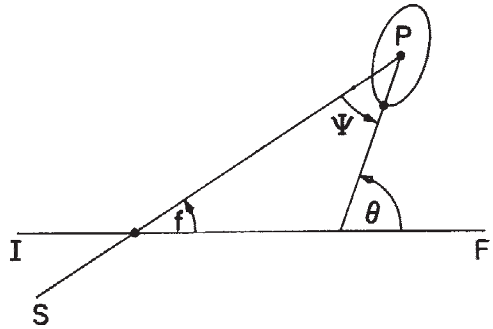

Fig. 1