Earth science

The changing shape of the Earth

from W.M. Kaula

THE tracking of Earth satellites continues to produce new findings about Earth properties. The most recent finding, reported in this issue of *Nature* (p.757), uses 5.5 years' laser ranging to Lageos, a 60-centimetre ball of brass covered by retro-reflectors whose retrograde orbit lies at 6,000 km altitude and is inclined at 73° to the ecliptic plane. The analysis demonstrates an acceleration of the node, the point where the ecliptic plane and the orbit of the satellite intersect. The acceleration could arise only from a rate-of-decrease, $\dot{J}_2$, in the oblateness of the Earth of $-3 \times 10^{-11}\text{yr}^{-1}$. This result was obtained by C.F. Yoder of Jet Propulsion Laboratory and collaborators at JPL and the University of Texas in Austin. An estimate of $\dot{J}_2$ (25 per cent lower) has also been reported by D.P. Rubincam of NASA Goddard Space Flight Center at the Fifth Annual NASA Geodynamics Program Conference and Crustal Dynamics Project Review in January.

This diminution of J_2 requires a motion of mass towards the rotation axis of the Earth, which reduces the difference between the equatorial and polar moments of inertia, to which J_2 is proportionate. The motion most plausibly arises from the Earth's internal adjustments following the last deglaciation, involving resurgence of material beneath the lithosphere towards Laurentia and Fennoscandia, where the great ice caps melted some 100,000 years ago — probably the greatest trauma received by the solid Earth in at least 10,000 years. The decrease in J_2 is consistent with a previously observed increase in the Earth's rotation rate, by conservation of angular momentum. This 'non-tidal acceleration' is itself inferred from satellite observations: first, of the total rotational deceleration, which is the sum of tidal and non-tidal components; and second, of the acceleration of the Moon's orbit, to which the tidal acceleration of rotation is proportionate. The lunar acceleration was a subject of debate for at least a century, and has been determined to two significant figures only recently by Yoder's JPL colleagues J.G. Williams and J.O. Dickey, who analysed 13 years of laser-ranging to the Moon.

While the determination of $\dot{J}_2$ is essentially a confirmation of another datum, it is a significant milestone in that it is the first clear-cut demonstration of a secular change in the Earth's gravity field. Tidal oscillations in the gravity field have, of course, long been measured by gravity meters. But the establishment of long-term trends from surface measurements has been plagued both by instrumental difficulties and by shallow effects of transitory or local interest, such as groundwater motion.

The determination of $\dot{J}_2$ is the latest achievement of the NASA Geodynamics Program, which is as old as the space age itself — the establishment of the value of J_2 to four significant figures (rather than two) in 1958 was the first precise quantitative result of the space effort. Initially, geodetic inferences from satellites were by-products. But since 1962 there have been a dozen or more spacecraft primarily directed towards determining either precise locations or variations in the gravity field. However, as missions become fewer and farther apart because of the great expense of significant new capabilities, satellite geodesy tends to lose out for several reasons. First, its results are not quickly achieved and appreciated; there are no striking images in the first month, but rather tedious numbers after long and painstaking tracking and data analysis. Second, the results are often of military interest and hence unavailable. And third, the scientific use is bound up with that obscure and ill-measured entity, the Earth's interior, whose inaccessibility leads to ambiguity of interpretation.

Thus new results in satellite geodesy in the last few years have come not from new missions, but from refinements of tracking systems and data analyses. The leading candidate for a new mission, satellite-to-satellite range-rate (currently named GRM, 'geopotential research mission') was initially proposed in 1969, but at the moment its launch seems unlikely before 1990, even though it will help to elucidate the structure of tectonically important areas such as the Andes and the Alpide belt. Meanwhile, there has been a cessation of more than a year of laser ranging to the Moon from the leading facility, McDonald Observatory in west Texas. □

W.M. Kaula is Professor of Geophysics in the Department of Earth and Space Sciences, 3806 Geology Building, University of California, Los Angeles, California 90024.

NOTES

THE *Union Médicale* of June 2 announces a discovery of the highest scientific interest, and which, if it turns out to be real, will show that prehistoric man is no longer a myth. On piercing a new gallery in a coal-mine at Bully-Grenay (Pas-de-Calais), a cavern was broken into containing six fossil human bodies intact — a man, two women, and three children — as well as the remains of arms and utensils in petrified wood and stone, and numerous fragments of mammals and fish. A second subterranean cave contained eleven bodies of large dimensions, several animals, and a great number of various objects, together with precious stones. The walls were decorated with designs of combats between men and animals of gigantic size. A third and still larger chamber appeared to be empty, but could not be entered in consequence of the carbonic acid it contained, which is being removed by ventilators. The fossil bodies have bene brought up to the surface, and five of them will be exhibited at the *mairie* of Lens; the others are to be sent to Lille in order to undergo examination by the Faculté des Sciences. Representatives of the Académie des Sciences of Paris and of the British Museum having been telegraphed for, are expected to be present.

We have received the Report of the Royal Victoria Coffee Hall, where, as may be known to many of our readers, much good work is being done at the present time in the way of providing cheap amusement every night, free from the temptation to drink and other evils common to ordinary music halls. Among other experiments being tried are short lecturers of the simplest and most popular kind, generally on some scientific subject illustrated by the oxyhydrogen lantern. We are told that a really good lecturer who understands his audience as well as his subject meets with a most encouraging reception, but that very few men of science give their assistance in this good work. We regret this; but we believe it is largely due to the fact that very little is known of the work in question, and that if a general appeal were made to those men of science who occasionally give an account either of their own work or the work of others, many would be found willing to join in the effort which is now being made to interest the working classes in science in what was formerly the Royal Victoria Theatre.

THE National Museum at Washington is one of the best examples in the United States of the practical application of electricity. In so large a building it was found advisable to take advantage of the best means of communication, first being its system of telephones and call-bells, by which those in any room can communicate with every room in the building. Twenty-six telephones are connected by a local telephone exchange, which in turn is connected with the main telephone office of the city. The result is that but three messengers are needed in this vast establishment. The photographic laboratory is independent of the sun, owing to the electric light there used. If one of the 850 windows or 230 doors is opened, a bell rings, and an electric annunciator shows to an attendant at the main office which window or door it is. This system is soon to be applied to every case of specimens. The watchmen at night, also, are kept to their posts by hourly releasing an electric current at certain stations, which pierces a dial and records their visit. The sixteen clock dials are likewise run by electric currents.

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