SATELLITES IN THE STUDY OF EARTH'S INTERIOR

(Dr. M. N. Qureshy, Adviser, Department of Science and Technology, Government of India, addressed the Fellows of the Geological Society of India on the subject: 'Satellites in the Study of Earth's Interior'. A synopsis of his talk is presented here for the information of non-residential Fellows—Ed.)

Presputnik era: Interest in knowing the exact shape of the earth is centuries old. The radius of the earth was worked out in the 8th century. Approximate mass of the earth was obtained by measuring the gravitational acceleration (g) at the surface and solving for m in the equation based on the Newton's Law of gravitational attraction, $g = G\frac{m}{R^2}$. From the known values of m and R, the average density of the earth was found to be 5.52 g/cm^3. Since the surface rocks have a density of about 2.7 g/cm^3, it was surmised that density must increase inside the earth; thus implying that the distribution of density inside the earth is not uniform and that the earth is a vertically differentiated planet. This method gave only a gross idea of the density of the earth and its distribution which has been much improved, using the sister discipline of earthquake seismology.

The study of the earth's shape was made possible through the application of mathematics. Stokes in 19th century showed that, with gravity field known at all the points on the earth's surface, its shape could be obtained. It is through Stokes' mathematical formulation that geoid or exact shape of the earth was obtained by using gravity field. As in gravity so in magnetism, through the mathematical formulations of Gauss, it became possible to differentiate between the internal (emanating from within the earth) and external (emanating from outside the earth) magnetic fields observed on the surface of the earth.

Up to the Sputnik era, the observations were mainly on the surface of the earth and were piece-meal. This inhibited a synoptic look at the earth as a planet. The launching of Sputnik in 1957 during the International Geophysical Year gave birth to an entirely new era of geophysical studies about the earth.

Sputnik and after: Many different types of satellites have been launched subsequent to Sputnik's launching.

From perturbations in orbits of satellites, the gravitational field of the earth could be derived and thus a more accurate shape of the earth could be arrived at. These results show that the earth is more like a pear than the oblate spheroid it was believed to be earlier.

Besides the studies of the gravitational field of the earth and geoid, the satellite-derived gravity data have also given an insight to the mega-tectonics of different parts of the world. With the increased sophistication in computers, data processing and interpretation techniques, it has become possible to glean through subduction zones, convection cells and thermal regimes in the mantle using satellite data. Likewise meaningful correlations and deductions about the stress distribution, convection pattern, and faults have been worked out in different continents. The SEASAT and GEOS-3 data have provided much finer gravity field on the sea which was near nonexistent earlier and have also given, for the first time, the actual sea surface within centimeters.

Apart from the gravity field, the launching of orbital geophysical observatories (OGO ; POGO ; GEOS 1, 2, 3 ; MAGSAT) have provided a wealth of geophysical information. Significant magnetic anomalies were obtained on major tectonic features like Hoggart – Tebesti volcanic field in the African Sahara and a very prominent anomaly in the equatorial Africa (Bangui anomaly).

MAGSAT and after: Magsat orbited in 1979 for six months, has provided better resolution than was available from POGO data. These data have been fruitfully utilized for elucidating the structure and even genesis of broad features like major tectonic boundaries, suture zones, sedimentary basins, subduction zones, rift zones, collision zones, Precambrian shields, ocean floor spreading, oceanic ridges, and the like. The Magsat data analysis, particularly when coupled with aeromagnetic and ground-based geophysical data, has opened new vistas for improving our understanding of many geological phenomena.

Use of mathematical techniques like harmonic and spectral analyses has made it possible to split the observed magnetic field from satellite heights, besides the external and internal fields, into the crustal component as well. Use of these techniques has also led to the mapping of magnetisation on continental scale. Thus magnetization distribution maps of India, USA and other parts of the world have been prepared.

Magsat data interpretation has given impetus to measurements of magnetic and other petrophysical parameters. These measurements of rock (xenoliths) samples, representing the entire crust and upper mantle, have enabled a better understanding of the magnetization of the crust and mantle, leading to inferences of long range consequences such as the nature of Moho. A general tendency towards a direct relationship between magnetization and grade of metamorphism has been noted, except when the Curie point is reached. The most important effect on large scale magnetization variation is probably the metamorphic transition. Thus it has been found that lherzolite and garnet pyroxenite are virtually non-magnetic. On the other hand, a suite of pyroxenites was found to be moderately magnetic and a suite of mafic granulites highly magnetic. It also implies that the lower crust is more magnetic than the upper crust; Moho constitutes the bottom of magnetic crust; and the mantle is, by and large, non-magnetic. These results are in harmony with the recent findings from exploration seismology that the lower crust may be a transition zone, probably formed of alternate layers of mafic and ultramafic composition.

Using Magsat data, radius of the core within 1.8% of seismically determined value, has been calculated. Fluid motions on the surface of the core have also been mapped.

From the present state of knowledge, the following magnetic zonation of the earth's interior may be surmised :

Near non-magnetic uppermost crust (sediments)
Less magnetic upper crust (Precambrian basement and granitic crust)
More magnetic lower crust (granulitic, and Fe-Ti oxides)
Non-magnetic mantle (chromium spinels and magnesium ilmenites)
Core – the source of major component of earth's magnetic field.

The future: NASA proposes to launch a new Mission, GEOPHYSICAL RESEARCH MISSION. It will measure gravity and magnetic fields at orbits lower than that of MAGSAT, at about 160 km altitude. It will provide much finer resolution and generate data that might enable study of geological structures of wavelengths (order of 100 km) much smaller than could be studied so far from satellites altitude of the order of 400 km. The advantages, needless to say, are many including the global data availability in a consistent system.

Concluding remarks: In the Indian context, much is yet to be done in making a better use of satellite data in attacking some of the basic problems of the evolution of the Indian lithosphere. We need increased efforts in the area of mathematics, for separation of fields from core, crust and external sources, laboratory measurements to evolve a comprehensive petrophysical properties data base including the effect of high temperature and pressure on these properties; seismic and electromagnetic characterization of Indian lithosphere, aided by some deep drilling, and forward modelling to decipher the cause of the observed anomalies and other tectonophysical significance.

M. N. QURESHY

SEDIMENTARY BASIN ANALYSIS

Basin analysis is the ultimate act of synthesis in stratigraphy. Its objective is to weave together the diverse strands of information in order to portray the tectonic evolution of a basin, its filling with sediments and the localization therein of mineral and petroleum resources. Thus, although the primary emphasis in basin analysis is stratigraphic and sedimentologic in nature, palaeontologic, tectonic and geophysical data, among others, are also integral components of the effort. It is scientifically challenging and in practical terms, forms the foundation for the exploration of strata-bound resources. The wide range of topics that must be incorporated into a basin analysis require that it be a group project of specialists.

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SHORT COURSE ON PALAEOPEDOLOGY

In the past few years, the importance of pedogenic layers in sequences has been increasingly realised. However, this aspect of Geology and Stratigraphy has generally been neglected.

A short course on Palaeopedology is being organised under the aegis of the Geological Society of India at Bangalore or Poona. It is proposed to hold the one-week course in April/May, 1987. The course will be conducted under the direction of Dr. S. K. Tandon (University of Delhi), Professor V. Subramanian (J. N. U., Delhi) and Professor S. N. Rajguru (Deccan College, Pune).

Earth Scientists (Geomorphologists, Sedimentologists, Stratigraphers, Pedologists, Archaeologists, etc.) with interests in Palaeopedology are encouraged to apply for this course.

A fee of Rs. 500/- will be charged for the course. Intending participants are advised that they should arrange for financial sponsorship from their respective institutions. Application forms will be available upon request from: **The Secretary, Geological Society of India, B. B. D. Press, Cottonpet, Bangalore-560 053.**