

News

A Well-Layered Earth

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Shortly after its accretion, Earth was both hot and heterogeneous, according to Don Anderson of the Seismological Laboratory at the California Institute of Technology (Caltech) in Pasadena, President-Elect of AGU. In a talk to be presented at the 1987 AGU Fall Meeting in San Francisco, Anderson draws on advances in seismology, petrology, and geochemistry for a hypothesis that Earth's mantle has been well differentiated, made up of concentric layers of different kinds of rock, throughout its history.

Classic theories of Earth's accretion hold that the mantle, that part of the planet lying between the iron-rich core and the thin rind of quartz-rich material that makes up the crust, was homogeneous soon after forming when the Solar System condensed from a vast cloud. Anderson, however, believes that Earth was assembled from very large objects and that the resulting high-energy environment led to heterogeneity in the new object's interior. High temperatures, combined with significant differences in the melting temperatures and densities of different rocks, gave rise to chemical zonation of the evolving planet. An important part of this theory of early postaccretion history is the existence and persistence of a huge magma ocean near Earth's surface, formed primarily from melting of the upper part of the mantle.

More recently, according to Anderson, the heterogeneity of the mantle has been maintained, despite the vigorous recycling of the crust by plate tectonics. This idea is supported by evidence presented in related seismology papers by Anderson and two of his Seismological Laboratory colleagues, Robert Clayton and Hua-Wei Zhou. In this work, they describe the behavior of slabs of ocean crust shoved at an angle into the mantle at subduction zones. Anderson and his colleagues have modeled the deep structure of subducted

slabs by seismic tomography, a technique of inverting seismic waves to construct a series of two-dimensional cross sections that can be assembled into a three-dimensional picture of Earth.

The scientists found that the slabs appear to flatten or break up about 650 km below the surface. A recognized discontinuity in seismic velocity at that depth is thought to be caused by deviations in composition from the material above and below. The discontinuity is called the "transition zone," the boundary between the upper and lower mantle. The slab flattening implies that the crust created by the partial melting of the mantle is not recycled completely into the lower mantle by subduction and melting of the slab. If the crustal slab does not penetrate the discontinuity, the composition of the lower mantle does not change, and chemical zonation is preserved.

Anderson also cites geochemical evidence to support the theory that the peridotitic upper mantle and perovskite-rich lower mantle have been chemically independent through Earth's evolution, separated by the transition zone, although tomographic modeling shows that there have been exchanges of heat between the two zones. According to Anderson, a transition zone is probably made primarily of "piclogite" (the garnet-pyroxene rock eclogite with moderate amounts of olivine). It is the partial melting of piclogite, he suggests, that yields the magmas that rise into the upper mantle to form basalts, creating new oceanic crust at diverging midocean ridges or interacting with existing crust on continents or at oceanic islands like Hawaii. —WWM

NASA to Call for Platform Proposals

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In mid-January 1988 the National Aeronautics and Space Administration (NASA) plans to issue an Announcement of Opportu-

nity (AO) for the Earth Observing System (EOS). This call for proposals will include Earth science research using the Space Station Polar Platforms and the initial manned Space Station. Other areas of space science will be offered the opportunity to propose secondary science experiments for flight with EOS on the Polar Platforms.

NASA's AO will solicit plans for instrumentation, data analysis, and theoretical investigations and for participation on the science teams for six large-facility instruments that NASA has under study for EOS. Similar announcements from the European Space Agency (ESA) and the Space and Technology Agency (STA) of Japan will be issued at the same time as the NASA EOS AO. All of the NASA and ESA programs, as well as proposals in the STA dealing with data analysis, will be open to the international community.

A copy of the NASA AO for EOS and the STA AO may be obtained by writing to Dixon Butler, EOS Program Scientist, Mail Code EPM-20 (EOS), NASA Headquarters, Washington, DC 20546. The ESA AO will be available from Phillip Goldsmith, Director, Earth Observation and Microgravity Programmes, ESA Headquarters, 8-10 rue Mario-Nikis, 75738 Paris Cedex 15, France. Requests for these announcements should reach NASA and ESA by January 6, 1988.

NASA is preparing a Background Information Package (BIP) to accompany the EOS AO. The BIP will contain important, detailed information for those who plan to propose and can be requested at the same time as the NASA AO. The 8-kg package will be mailed U.S. First Class. Researchers who prepay or send a completed airbill including account number can receive the package by their choice of any expedited delivery service with a Washington, D.C., drop-off point.

This item was contributed by Dixon Butler, NASA Headquarters, Washington, D.C.

NSSDC Releases Version 1.0 of the NSSDC Graphics System (NGS)

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Pictorial or visual representations of data are critical to understanding those data, particularly in support of correlative data investigations. This is a concept that the National Space Science Data Center (NSSDC) has recognized for several years and that has begun to grow in importance among the scientific community at large recently. The National Science Foundation's report, *Visualization in Scientific Computing* (July 1987) has a succinct discussion of the idea.

To implement the concept for the space and Earth science research community, NSSDC has an ongoing program to develop new, generic (i.e., data-independent) techniques for the display of multidimensional

Cover. An example of the kind of data visualization that can be generated by the new version of a graphics system produced by the National Space Science Data Center (NSSDC). This montage illustrates the results of the reduction in total ozone observed during the Antarctic spring last year. It shows daily ozone data from October 14, 1986, through October 17, 1986, as an animated sequence (upper left, upper right, lower left, and lower right, respectively). Each day of data is visualized as a three-dimensional object centered over the south pole in an azimuthal equidistant projection. The displays show total ozone in terms of Dobson units, which is represented by both the pseudo-color spectrum and height. The height mapping dramatizes the concept of a *hole* in the ozone layer, while the color enhances this perception as a terrain color would enhance a topographic map. Other visualization techniques (for example, high-res-

olution pseudo-color imagery) might emphasize the detailed, quantitative evolution of the spatial structure instead. This technique emphasizes qualitative information and shows the temporal and coarse spatial evolution of the total ozone over the 4 days.

The data used by the NGS to create these displays are derived from the Total Ozone Mapping Spectrometer (TOMS) on board the National Aeronautics and Space Administration's Nimbus 7 spacecraft. The data are available as daily world grids from late 1978 through the present and are archived at the NSSDC.

For more information about the graphics system, see the news item "NSSDC Releases Version 1.0 of the NSSDC Graphics System (NGS)" on page 1610. (Image and explanation courtesy of Lloyd A. Treinish, NSSDC, NASA/Goddard Space Flight Center, Greenbelt, Md.)

data and information about these data or metadata. The techniques use the latest methods in computer graphics and imaging, as well as state-of-the-art hardware.

NSSDC has developed the NSSDC Graphics System (NGS), an interactive discipline-independent toolbox to support the visualization of data on the NSSDC Computer Facility (NCF) machines, a DEC VAX 8650 and a VAX 11/780. To use the NGS, data of interest must be stored in the NSSDC Common Data Format (CDF), a data-independent abstraction for multidimensional data structures. The CDF has been used to develop a number of generic data management, display, and analysis tools for a wide variety of disciplines at NSSDC. The CDF development efforts are evolving into a standard method for storing space and Earth science data for a variety of applications. (See "A Software Package for the Data-Independent Management of Multidimensional Data," by L. Treinish and M. Gough, in *Eos*, July 14, 1987, pp. 633 for a description of CDF.)

To develop the required graphical capabilities in as timely and cost-effective manner as possible, NSSDC has employed several off-the-shelf capabilities. The NGS employs the National Aeronautics and Space Administration's Transportable Applications Executive (TAE) as an easy-to-use, consistent, uniform user interface. As TAE evolves into supporting an object-oriented window-based interface, the NGS will adopt these improvements. To support two- and three-dimensional interactive graphics on any type of graphics hardware, the NGS employs the TEMPLATE package, developed by TEMPLATE Graphics Software. In addition to providing the environment and the tools to generate graphics, TEMPLATE provides the NGS with sophisticated graphics device-independence for both direct as well as postprocessing of graphical objects. As this package evolves and expands in capability, the NGS will take advantage of these enhancements.

The NGS supports the ability to display or visualize any arbitrary multidimensional subset or slice of any data set by providing a large variety of different representation schemes, all of which are supported by implicit animation. In other words, any field within one or more CDF-based data sets can be used for any axis, including sequencing for animation. In addition, the NGS places a strong emphasis on complete annotation of its graphical products, and extensive use of color. The NGS supports the following ways of displaying data:

- two-dimensional histogram
 - X-Y plots (including optional multiple axes, pseudo-color and polar coordinates)
 - multiple panel displays
 - location maps
 - contour plots with and without maps
 - surface diagrams with and without maps (including optional pseudo-color)
 - pseudo-color images with and without maps
 - solid modeling without maps
- In addition, the NGS will support these visualization techniques in the future:
- solid modeling with maps
 - X-Y-Z plots with and without maps
 - two-dimensional vector field plots with and without maps

- three-dimensional vector field plots with and without maps
- three-dimensional histograms with and without maps

The NGS also provides a number of options for each representation scheme, such as curve fitting, gridding, scaling, filtering, font selection, statistics, graphics metafile generation, and so on. Specific options are associated with all representation schemes (e.g., controlling the range and increment of isolines on contour maps).

The NSSDC has placed a very strong emphasis in the NGS development effort on providing very accurate, high-performance graphics tools for data visualization. For example, to support the visualization of large, geographic data sets the NGS employs very flexible world mapping capabilities that are not only quick but also very precise to eliminate any distortion in mapped displays. Currently, 22 general projections are supported, while more can be easily added by user request. The user has complete control over the specification of the pole point and viewing window for any of the display techniques available with world maps to support arbitrary reprojection of any data set. Both low and medium resolution world coastline data bases are supported, the latter with political boundaries. In the future, a very high-resolution world coastline data base will be added as well as a world topographic data base.

The design of the NGS provides an open-ended framework for discipline-independent data visualization, so that new capabilities can be added. New tools are being implemented as a result of NSSDC's research in several areas, which is an outgrowth of previous efforts supported by the GSFC Director's Discretionary Fund for interactive solid-modeling techniques employing NASA's Massively Parallel Processor (MPP). For example, the following specific new techniques have been recently developed:

- Advanced data structures that support graphics as well as data analysis and management applications to assure rapid display and manipulation of large, complex data sets:
 - storage and sampling of three-dimensional data via generic oct-trees
 - polygon expansion via quadtree-based rectangular subdivision for pseudo-color imagery
- Rendering and manipulation algorithms with serial (e.g., VAX) and parallel (e.g., MPP) implementations that can operate on any data object or geometry:
 - n -dimensional gridding
 - ray tracing via recursive spherical triangle subdivision

The NGS is designed to be portable so that copies eventually can be made available on computer systems outside of the NCF to promote the exchange of both software and data. In fact, it is expected that the NGS will be β -tested at several sites on the Space Physics Analysis Network (SPAN) by late 1987 to evaluate it for potential use in future flight projects as well as to support specific scientific investigations. In addition, the NGS is currently available operationally to the users on SPAN of NSSDC's Network Assisted Coordinated Science (NACS) system in support of the Coordinated Data Analysis Workshop (CDAW). It will be available to users of NSSDC's NASA Climate Data System (NCDS)

in the future. To properly support the diverse use of the NGS, the software is maintained with strict configuration control under NSSDC management.

In the future it is hoped that this work will be expanded to support the implementation of the NGS into low-cost graphics workstations (e.g., Apple Macintosh II) as well as high-performance graphics workstations (e.g., Silicon Graphics IRIS) and the support of production of presentation-quality animated visualizations. In such an operational environment an analyst would use the various conventional NGS tools to examine data of interest at different levels of detail and then interactively view a solid geometry model of the data in three dimensions on a graphics workstation, including the examination of sequences of such models. A user could optionally invoke the MPP or the NASA Space and Earth Sciences Computing Center CDC Cyber 205 to prepare the geometries or otherwise manipulate the data in a timely and straightforward manner. After such an examination, a user could visually choose an appropriate orientation for the geometries, and then request a ray-traced image(s) or animated sequence to be generated on the MPP or Cyber 205.

This report was contributed by Lloyd A. Treinish, National Space Science Data Center, NASA/Goddard Space Flight Center, Greenbelt, Md.

More Radar for Space Shuttle Imaging Mission

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NASA's space shuttle is to enhance its third space-borne imaging radar mission (SIR-C) under the terms of an agreement signed October 6, 1987, between NASA (the National Aeronautics and Space Administration) and the science ministry of the Federal Republic of Germany (FRG). The agreement provides for the joint FRG and Italian development of an X band synthetic aperture radar (X-SAR) system to be flown on at least two of the shuttle's imaging radar missions. NASA also has plans to fly an advanced X-SAR system on a polar platform with its Earth Observation System.

The SIR-C mission will carry radar equipment operating in three different frequency bands (L band, C band, and now X band) and capable of imaging a given scene from a number of different angles. Scientists hope that data from the SIR-C mission will be useful in refining current models of Earth's surface and in developing improved remote sensing techniques.

NASA's Jet Propulsion Laboratory in Pasadena, Calif., will implement the SIR-C radar project; the FRG Aerospace Research Establishment and the Italian National Research Council's National Space Plan have set up a joint office in Cologne (that is, Köln, FRG) for the implementation of the X-SAR system.

—CBT