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U.K. GEOPHYSICAL ASSEMBLY

12-15 APRIL

1977

at

Department of Geophysics

James Clerk Maxwell Building

University of Edinburgh

CONTENTS

edited by K.M. Creer

1 Preface

In the spring of 1975 I put the suggestion to the Royal Astronomical Society that a national geophysical meeting be held in U.K. at which a wide variety of subjects would be discussed in parallel sessions along the lines of the annual meetings of the American Geophysical Union held in Washington. A few U.K. geophysicists expressed doubts as to whether sufficient interesting geophysics was being done in U.K. to sustain such a meeting. Nevertheless when the question of whether such a national meeting would attract their support was put to geophysicists in U.K. Universities and Research Institutes, it was apparent that wide support would be forthcoming at the grass-roots level.

At this stage Dr. J. A. Hudson, Geophysical Secretary of the R.A.S., proposed to Council that they should sponsor a national geophysical meeting. They agreed to do this and the U.K. Geophysical Assembly (U.K.G.A.) to be held in the University of Edinburgh (U.O.E.) between 12 and 15 April 1977 is the outcome.

A Local Organizing Committee was formed with Professor K. M. Creer (Geophysics, U.O.E.) as Chairman and with the following members: Dr. V. R. S. Hutton (Geophysics, U.O.E.), Dr. D. H. McIntosh (Meteorology, U.O.E.), Dr. P. L. Willmore (I.G.S. Global Seismology), Dr. W. F. Stuart (I.G.S. Geomagnetism), Mr. R. McQuillin (I.G.S. Marine Geophysics) and Mr. W. Barclay (Oil Exploration (Holdings) Ltd.).

Papers were invited on an open basis so that the content of the working sessions would reflect the nature and emphasis of the geophysical work currently being carried out in U.K. Contributions were grouped under seven section headings. Section convenors were given the responsibility of calling for papers and of composing the working sessions. Local co-convenors were appointed to coordinate the input to the different sections. Section titles, names of convenors and co-convenors, the number of papers finally contributed to each section and the number of working sessions formed from them are given below.

A Applied Geophysics and Glaciology

Convenor: Prof. D. H. Griffiths, University of Birmingham

Co-Convenor: Mr. R. McQuillin, I.G.S., Edinburgh

15 papers, 2 sessions.

F Magnetohydrodynamics and Meteorology

Convenor: Dr. D. J. Tritton, University of Newcastle

Co-Convenor: Dr. D. H. McIntosh, University of Edinburgh

14 papers, 2 sessions.

G Geomagnetism and Palaeomagnetism

Convenor: Prof. R. L. Wilson, University of Liverpool

Co-Convenor: Dr. V. R. S. Hutton, University of Edinburgh

50 papers, 6 sessions.

L Lithospheric Studies

Convenor: Prof. M. H. P. Bott, University of Durham

Co-Convenor: Dr. S. A. D. Bamford, University of Edinburgh

39 papers, 5 sessions.

M Magnetospheric, Ionospheric and Solar Terrestrial Phenomena

Convenors: Dr. H. Rishbeth, Appleton Laboratory, and
Prof. P. C. Kendall, University of Keele

Co-Convenor: Dr. W. F. Stuart, I.G.S., Edinburgh

30 papers, 6 sessions.

P Planetology

Convenor: Prof. A. H. Cook, F.R.S., University of Cambridge

Co-Convenor: Dr. R. G. Hipkin, University of Edinburgh

6 papers, 1 session.

S Seismology

Convenor: Dr. H. Thirlaway, A.W.R.E., Blacknest

Co-Convenor: Dr. P. L. Willmore, I.G.S., Edinburgh

28 papers, 5 sessions.

Four General Lectures have been invited. They will be delivered to the whole Assembly at 09.00 and at 14.00 on Wednesday, 13 and Thursday, 14 April. The names of the invited speakers and the titles of their lectures are given in Section 2. Working sessions, run in parallel, will commence at 09.45 and at 14.45 on these days following the General Lectures and will also be held during Tuesday, 12 April after the Opening Ceremony, and during the morning of Friday, 15 April. The content of each of the working sessions is given in Section 3. Abstracts of papers to be presented, grouped section by section, are presented in Section 4. Finally, an author index is given in Section 5. A time-table will be circulated.

The Local Organizing Committee wishes to take this opportunity of expressing its hearty thanks to the Council of the Royal Astronomical Society for generous financial backing without which it would have been impossible to hold this U.K. Geophysical Assembly. Thanks are also due to the University of Edinburgh for the many facilities placed at the disposal of the L.O.C. On behalf of all delegates to U.K.G.A., we thank both the City of Edinburgh and the University of Edinburgh for invitations to Receptions offered to delegates respectively on the Tuesday and Wednesday evenings. Thanks are also expressed to Miss Kathy Dodds, my secretary, who typed this copy and who also had to retype many of the submitted abstracts to bring them up to the standard required for reproduction, to Mrs. Inger Banks, the Conference Secretary, and to Mr. S. Ballantyne and Mr. N. Aikman of the University of Edinburgh Audio Visual Services Unit who prepared the copy for the printer.

Edinburgh,
10 February 1977

K. M. Creer,
Chairman, Organizing Committee.

2 General (Invited) Lectures

09.00, Wednesday, 13 April 1977:

I3 A Geophysicist's Approach to the Moon and Planets.

Professor S. K. Runcorn, F.R.S.,
Institute of Lunar and Planetary Science, University of Newcastle upon Tyne.

14.00, Wednesday, 13 April 1977:

I2 Reversals of the Earth's Magnetic Field.

Professor J. A. Jacobs,
Department of Geodesy and Geophysics, University of Cambridge.

09.00, Thursday, 14 April 1977:

I1 Planetary Atmospheres and the Emerging Perspective.

Dr. G. E. Hunt,
Meteorological Office, Bracknell.

14.00, Thursday, 14 April 1977:

I4 Marine Magnetic Anomalies.

Professor F. J. Vine, F.R.S.,
School of Environmental Sciences, University of East Anglia.

3 Content of Sessions

SESSION AI

Applied Geophysics

Chairman: Dr. M. A. Khan

A9 Holographic Mapping of Coal Seams Using Channel Waves.
I. M. Mason and D. J. Buchanan

A3 3-D Data Collection and Display.
M. J. G. Cox and W. R. Cotton

A1 In Situ Seismic Measurements of Crack Anisotropy.
D. Bamford and K. R. Nunn

A10 A Shallow Land Seismic Reflection System Using a Vibrator Source.
E. G. Webb and K. R. Nunn

A7 Marine Geophysical Surveying in Engineering Studies of Coastal Zones.
D. M. McCann and R. A. Floyd

A5 In-Situ Electrical and Acoustic Measurements - An Aid to Rapid Geotechnical Mapping on the Sea-Floor.
P. D. Jackson and R. Baria

A6 Transformation of Magnetic into Pseudo-Gravity Anomalies Using an Interactive Graphics Terminal.
C. McCann

A11 Joint Modelling of Gravity and Magnetic Anomalies Using Non-Linear Optimization.
G. K. Westbrook

SESSION AII

Applied Geophysics and Glaciology

Chairman: Dr. R. F. King

A2 The Use of Geophysical Methods in Locating Buried Valleys in N.E. England.
J. D. Cornwell, E. M. Andrew, C. Johnson and M. K. Lee

A8 A Comparison of I.P. Transient Shapes over Disseminated and Massive Sulphide Sheets in the Lower Pillow Lavas of Cyprus.
G. Maliotis and M. A. Khan

A12 A Borehole Controlled Source Induction Procedure for the Determination of Electrical Conductivity Structure.
M. H. Worthington

A4 A Deep Resistivity Sounding at Rookhope Co. Durham.
G. M. Habberjam

A13 Surface Strain Rate Measurements of Sea-Ice and Glaciers.
D. J. Goodman

A14 The Radio Frequency Bi-Refringence of Polar Ice Sheets.
N. D. Hargreaves

A15 Radar Techniques in Glaciology and Other Fields - A Review.
D. T. Meldrum

SESSION FI

Magnetohydrodynamics and Meteorology

Chairman: Dr. D. Tritton

F8 A Study of the Stratification in the Earth's Outer Core.
T. G. Masters

F9 Hydromagnetic Effects Near a Bumpy Core-Mantle Interface.
H. K. Moffatt

F3 Generation of Magnetic Fields by Fluid Motions of Global Scale.
D. Gubbins

F1 Magnetohydrodynamic Wave Energy Flux.
J. A. Adam

F5 The Transport of Ozone in a Time-Dependent, Two-Dimensional Model.
R. S. Harwood and J. A. Pyle

F10 Prognosis of Ozonolytic Pollution.
R. S. Scorer

F7 On Detached Shear Layers and Western Boundary Currents in a Rotating Homogeneous Liquid.
L. M. Hocking and R. Hide

SESSION FII

Magnetohydrodynamics and Meteorology

Chairman: Dr. D. H. McIntosh

F12 Convection in Rapidly Rotating Fluid Spheres.
A. M. Soward

F13 Internal Gravity in a Shear Flow.
S. A. Thorpe

F2 The Spectrum of Lee Waves in Stratified Flows.
F. H. Berkshire

F11 Non-Linear Baroclinic Disturbances to Mid-Latitude Zonal Flows.
A. J. Simmons and B. J. Hoskins

F6 Thermal Convection in a Rotating Fluid Subject to a Horizontal Temperature Gradient: Spatial and Temporal Characteristics of Fully Developed Baroclinic Waves.
R. Hide, P. J. Mason and R. A. Plumb

F4 The Observed Flux of Potential Vorticity in the Stratosphere.
R. S. Harwood

F14 Aspects of Geophysical Turbulence.
J. D. Woods

SESSION GI

Geomagnetic Main Field and Secular Variation

Chairman: Mr. S. R. C. Malin

G1 Does the Geomagnetic Field Have a Significant Monopole Component?
D. R. Barraclough

G2 A Definitive Model of the Geomagnetic Field of Epoch 1975.
D. R. Barraclough, J. M. Harwood, B. R. Leaton and S. R. C. Malin

G3 Synthetic Plots Obtained from an Oscillating Alldredge-Hurwitz Radial Dipole Model.
K. M. Creer and T. E. Hogg

G4 The (IN) Significance of the Correlation between the Earth's Gravitational and Magnetic Fields.
F. J. Lowes

G50 A Geomagnetic Test of Maxwell's Equations.
R. L. Wilson, C. R. Johnson, A. G. MacCormack and D. R. Barraclough

SESSION GII

Geomagnetic Field Behaviour Studies

Chairman: Professor R. L. Wilson

G5 A Layman Looks at Dynamo Theory.
F. J. Lowes

G28 Speleomagnetism - The Paleomagnetic Record Carried by Cave Sediments.
J. S. Kopper

G31 Preliminary Results of a Palaeomagnetic Investigation of Lake Sediments from Poland.
E. Niedziolka, P. Tucholka and T. E. Hogg

G25 Secular Variations Obtained from French and Swiss Lakes 0-6000 Years B.P.
T. E. Hogg

G35 Geomagnetic Field Fluctuations Recorded in Sediment from Lake Trikhonis, Greece.
P. W. Readman

G30 Palaeomagnetic Studies of Varved Clays from Poland.
E. Niedziolka

G33 Post-Depositional Remanent Magnetization in Sediments from the Greek Lakes.
S. Papamarinopoulos

G19 A New Method for Determining the Magnitude of the Earth's Magnetic Field Using Sun-Dried Bricks.
K. P. Games

G20 Geomagnetic Archaeomagnitude Measurements from Peruvian Ceramics.
N. M. Gunn

G16 Experiments Relating to Fundamental Problems in Archaeomagnetic Field Strength Measurements.
M. F. Barbetti, K. P. Flude and J. M. W. Fox

G38 Archaeomagnetic Intensity Measurements Using a Squid Magnetometer.
D. Walton and M. J. Aitken

SESSION GIII

Younger Palaeomagnetism

Chairman: Dr. A. E. Mussett

G23 Magnetic Fabric of Marine Sediments.
N. Hamilton

G32 Some Uses of Induced Magnetic Measurements in Lake Sediments.
F. Oldfield, J. A. Dearing, T. A. Rummery and R. Thompson

G36 Low Temperature Demagnetization Investigations into the Carriers of Stable Natural Remanent Magnetization in Some Finnish Lake Sediments.
J. C. Stober and R. Thompson

G37 A Statistical Approach to Curve Fitting and Correlation of Serial Data Distributed on a Sphere.
R. Thompson and R. M. Clark

G22 Quaternary Palaeomagnetic Results from DSDP Sites 379 and 380 in the Black Sea.
E. A. Hailwood and N. Hamilton

G24 Late Neogene Magnetic Stratigraphy Evidence from DSDP Mediterranean Sea Sites 372, 374 and 376.
N. Hamilton and E. A. Hailwood

G17 Polarity Sequence of Mull.
P. Dagley and A. E. Mussett

G29 Problems of Polarity in the British Tertiary Igneous Province.
A. E. Mussett

G27 Palaeomagnetic Investigations of Tertiary Volcanic Activity in Lower Silesia, Poland.
M. Jelenska, M. Kadzialko-Hofmokl and J. Kruczyk

SESSION GIV

Geological Uses of Palaeomagnetism

Chairman: Professor J. C. Briden

G26 Continental Drift Between the Palaeozoic and Mesozoic.
E. Irving

G34 Palaeomagnetic Studies of the Pre-Cambrian: Britain, South Greenland and Scandinavia.
J. D. A. Piper and J. E. F. Stearn

G18 Palaeozoic Palaeomagnetic Results from Jersey, C.I.
B. A. Duff

G21 Mesozoic Geomagnetic Field Configuration and Circum-Atlantic Continental Reconstructions.
E. A. Hailwood

G15 Chemical Demagnetisation Studies of the Alderney Sandstone, Channel Islands.
J. A. Banner and E. A. Hailwood

SESSION GV

Rock Magnetism

Chairman: Dr. W. O'Reilly

G40 A Method for Preparation of Iron-Titanium Single Crystals.
Z. Hauptman

G42 Laboratory Simulation of Maghemitization and Deuteric Oxidation of Titanomagnetite-Influence on Coercive Force and Other Magnetic Properties.
J. B. O'Donovan

G45 A Magnetic Study of Synthetic Titanomagnetite Substituted by Aluminium.
O. Ozdemir

G41 Oxygen Fugacity Values and Curie Temperatures for the Middle Members of the Cubic Titanomagnetite s.s. Series.
Z. Hauptman and A. L. Campbell

G39 An Experimental Study of Ti Diffusion in Magnetite.
R. Freer and Z. Hauptman

G47 Magnetic Properties of Titanomagnetite Single Crystals.
P. Tucker

G48 Magnetic Interaction Between Iron and Ulvospinel.
R. Veitch and A. Stephenson

G46 Magnetic Properties of Ulvospinel.
P. W. Readman

G44 Magnetic Anisotropy of Deformed Calcite Aggregates.
W. H. Owens and E. H. Rutter

G43 Rotational Hysteresis in Haematite.
W. H. Owens

G49 A Rotating-Head Torque Magnetometer Controlled by a Microprocessor.
D. Wilson

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Geomagnetic Induction Studies

Chairman: Dr. R. Banks

G6 Effect of Conductivity Anomalies in Devon on Micropulsations.
C. C. F. Adcock, A. M. Hart, C. D. Honebon and W. G. V. Rosser

G11 The Interpretations of Geomagnetic Variation Observations in Scotland Using the Hypothetical Event Technique.
V. R. S. Hutton, J. Sik, A. G. Jones and D. Rooney

G12 A Method for the Processing of Magnetotelluric Data.
A. G. Jones

G13 A Comment on Methods of Solution of Oceanic Induction Problems.
P. C. Kendall

G14 Lunar Geomagnetic Tides and the Ocean Dynamo.
D. M. Schlapp

G7 The Representation of Internal Fields by Equivalent Currents in Thin Sheets: Application to GDS Array Studies in Kenya.
R. J. Banks and D. Beamish

G8 Local Conductivity Effects on the Magnetic Fields Due to Sea Tides.
A. M. Hart

G9 First Order Solutions of Oceanic Induction Problems.
R. C. Hewson-Browne and P. C. Kendall

G10 The Electrical Conductivity of the Moon: An Application of Inverse Theory.
B. A. Hobbs

SESSION LI

General Geophysics (U.K.)

Chairmen: Professor M. H. P. Bott, Dr. M. A. Khan

L22 Caledonian Granites: A Rare Thermal Event.
J. Hennessy and G. C. Brown

L27 Geophysical Modelling and Petrogenesis of the Shap Granite.
C. A. Locke and G. C. Brown

L26 A Geomagnetic Induction Study at Micropulsation Periods in the Southern Uplands of Scotland.
A. G. Jones and V. R. S. Hutton

L23 A Gravity Survey of the South Midlothian Coalfield and Southern Uplands Fault System.
R. G. Hipkin

L18 Geophysical Investigation of the Pre-Carboniferous Basement of the Askrigg Block Yorkshire.
J. D. Cornwell, J. M. Allsop, M. K. Lee and D. Patrick

L16 The Acquisition and Interpretation of a Gamma-Ray Survey over the Loch Doon Granite.
J. Cassidy, G. C. Brown and J. Hennessy

L31 A Geomagnetic Deep Sounding Study in Northern Scotland.
J. M. Sik and V. R. S. Hutton

L24 Secular Variation of Gravity in Scotland.
R. G. Hipkin

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Chairman: Professor M. H. P. Bott

L28 Results of Gravity and Magnetic Surveys in the Forties Area of the North Sea.
A. K. Rochester

L17 Geophysical Evidence on the Structure of the Faeroe-Shetland Escarpment.
J. A. Chalmers, A. Dobinson, A. Mould and D. K. Smythe

L19 An Interpretation of Gravity and Magnetic Data in the English Channel Around the Isle of Wight.
S. E. Deegan and A. Dobinson

Laboratory and Theoretical Studies

Chairman: Dr. R. F. King

L36 Isostatic Compensation of a Continental Scale: Local Versus Regional Mechanisms.
R. J. Banks

L37 Amplification of Upper Lithospheric Stresses by Underlying Viscoelastic Creep with Application to Continental Splitting Mechanism.
M. H. P. Bott and N. J. Kasznir

L39 Seismic Wave Propagation in Anisotropic Media: Importance for Lithospheric Studies.
S. Crampin

L38 Laboratory Measurements of Seismic Velocities and Electrical Resistivity of Rocks in Upper Crustal Conditions.
P. N. Chroston, C. Evans and C. Lee

L35 Laboratory Measurements of Seismic Velocities in Lewisian Metamorphic Rocks.
F. M. Al-Haddad

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Chairmen: Dr. D. Bamford, Dr. R. B. Whitmarsh

L11 The Crustal Structure Beneath Northern Britain.
K. Nunn (The LISPB Working Group)

L2 S Waves in the LISPB Crustal Profiles.
M. Assumpcao and D. Bamford

L6 Observations of PS Reflections from the Moho.
A. W. B. Jacob and D. C. Booth

L5 Lewisian Units Seismic Traverse.
J. Hall

L13 Seismic Refraction Studies of the Upper Crust in the East Midlands.
D. N. Whitcombe

L4 Long Seismic Lines in the Bristol Channel Area.
M. Brooks, M. Bayerly and D. J. Llewellyn

L3 Long-Range LISPB Observations.
D. Bamford (The LISPB Working Group)

L7 On the Inversion of Long Range Seismic Profiles.
B. L. N. Kennett

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Explosion Seismology (Margins and Oceans)

Chairmen: Dr. D. Bamford, Dr. R. B. Whitmarsh

L1 The Hebridean Margin Seismic Project of 1975.
A. R. Armour and M. H. P. Bott

L10 Display and Processing of Seismic Wide Angle Reflection Data from Disposable Sonobuoys.
P. R. Miles

L8 Towards a More Detailed Seismic Picture of the Oceanic Crust.
B. L. N. Kennett

L14 Detailed Studies of the Upper Oceanic Crust Using a Large Air Gun and Bottom Receivers.
R. B. Whitmarsh

L9 Thin Crust in the Philippine Sea.
K. E. Louden

L12 P Wave Structure of the Lithospheres (0-10 m.y.) North of the Azores.
L. Steinmetz, R. B. Whitmarsh and V. Moreira.

General Geophysics (Oceans)

Chairman: Professor M. H. P. Bott

L30 The Structure of King's Trough, North-East Atlantic, from Seismic and Gravity Data.
R. C. Searle and R. B. Whitmarsh

L34 Variation in Crustal Structure Along the Lesser Antilles Island Arc.
G. K. Westbrook

L29 The Structure and Origin of Kurchatov Fracture Zone, North Atlantic Ocean.
R. C. Searle and A. S. Laughton

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Chairman: Dr. M. A. Khan

L21 Recent Geophysical Studies of the Gulf of Aden.
R. W. Girdler and P. Styles

L15 Krisp 1975. Seismic Profiles Within the Gregory Rift Valley, Kenya.
T. J. Wilton

L33 A Gravity Map of Kenya.
C. J. Swain and M. A. Khan

L32 Regional Gravity Anomalies Over the East African Rift System.
W. T. C. Sowerbutts

L25 Geomagnetic Induction Studies in Kenya.
V. R. S. Hutton, D. Rooney, I. M. Brazier and E. Mbipom

L20 Crustal Development of the Central West Greenland Embayment.
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MIST

M7 Atomic Oxygen in the Mesosphere and Lower Thermosphere.
P. H. G. Dickinson

M8 The Scattering of Sunlight from Noctilucent Clouds.
M. Gadsden

M9 Some Characteristics of Cirrus Clouds Observed with a Steerable Lasar Radar.
A. J. Gibson, L. Thomas and S. K. Bhattacharyya

M10 Noctilucent Cloud Movements.
A. D. Jenkins

M11 Atmospheric Water Vapour of Extraterrestrial Origin.
D. M. Willis

M12 Theory of the Near Infra-Red Nightglow Continuum.
P. C. Wraight

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MIST

M15 Outer Radiation Zone Structure in a Simple Magnetospheric Model.
S. W. H. Cowley

M16 Recent Results on Magnetic Merging in Collisionless Plasmas.
S. W. H. Cowley

M21 Focusing of Whistlers by a Varying Magnetic Field.
M. J. Laird

M23 The Role of Hot Plasma in Magnetospheric Convection.
D. J. Southwood

M29 Temporal Variations in Total Equatorial Plasmaspheric Content and their Relationship to the Ring Current Intensity and the Plasmapause.
D. C. Webb and L. J. Lanzerotti

SESSION MIII

MIST

M1 Electrons and Positive Ions Associated with an Auroral Arc.
D. A. Bryant, D. S. Hall, D. R. Lepine and R. W. N. Mason

M2 Image Intensified Observations of Auroral Pulsating Patches.
J. Crawford, P. Rothwell and R. Thomas

M3 Suprathermal Particle Fluxes Associated with an Auroral Arc.
A. D. Johnstone and J. J. Sojka

M4 Observations of Pulsating Aurora.
D. J. McEwen and D. A. Bryant

M5 Energised Auroral Suprathermal Electrons.
J. J. Sojka and A. D. Johnstone

SESSION MIV

MIST

M6 Instability of a Field-Aligned Electron Beam.
R. J. Strangeway

M13 Relative Flow of H^+ and O^+ Ions in the Topside Ionosphere at Mid-Latitudes.
R. J. Moffett, G. J. Bailey and J. A. Murphy

M14 Ti Troughs in the Equatorial Topside Ionosphere.
H. Rishbeth

M19 Possible Effects of I.M.F. Sector Polarity on Sq.
J. G. Greener and D. M. Schlapp

M30 Stochastic and Dynamic Temperature Changes in the Interplanetary Gas.
M. K. Wallis and M. A. Hassan

SESSION MV

MIST

M17 Hydromagnetic Eigenmodes in a Simple Model Plasmasphere with a Thin Lower Ionosphere.
A. H. Craven and J. A. Lawrie

M18 Localised Pc4's which Occur at High Latitudes in the Midnight-Dawn Quadrant.
C. A. Green and W. F. Stuart

M20 A Pc4 Pulsation Observed Near Midnight at Geostationary Orbit.
W. J. Hughes, R. L. McPherron and J. N. Barfield

M22 Sources of Damping of Pc's.
R. S. Newton

M24 Particle Flux Variations Produced by Magnetospheric Hydromagnetic Waves.
D. J. Southwood and M. G. Kivelson

M25 Some Global Characteristics of Pulsation Activity.
W. F. Stuart and C. A. Green

M26 Secondary Resonance in Pi2's.
W. F. Stuart and P. M. Mills

M27 Long Period Continuous Pulsations at High Latitudes.
M. R. Warner and D. Orr

M28 A Comparison of ULF and VLF Measurements of Magnetospheric Cold Plasma Densities.
D. C. Webb, L. J. Lanzerotti and C. G. Park

SESSION MVI

EISCAT

Invited papers describing experiments currently proposed for the U.K. research programme using EISCAT European Incoherent Back Scatter Facility will be presented. Contributed papers will also be welcomed.

SESSION PI

Planetology

Chairman: Professor A. H. Cook, F.R.S.

P3 Towards a New Semi-Literal Theory of the Lunar Librations.
A. H. Cook

P6 The First 100 Million Years.
G. Turner, P. H. Cadogan and M. C. Enright

P5 Large Scale Processes on the Moon.
G. Fielder

P4 Determination of the Temperature and Duration of Some Apollo 17 Boulder Shadows Using Thermoluminescence Methods.
S. A. Durrani

P1 Micrometeorite and Solar Wind Erosion of the Lunar Surface.
D. G. Ashworth

P2 Evaporative Sources for Track Components of Planetary Atmospheres.
P. Brimblecombe and K. Hunter

SESSION SI

The Source

Chairman: Dr. J. A. Hudson

S4 Seismology in the Oceanic Microseism Band.
A. Douglas

S5 Earthquake Synthesis.
K. J. Fahmi

S12 Fault Plane Solutions Using P and pP Relative Amplitudes.
R. G. Pearce

S10 Ocean Bottom Seismograph Observations on the Mid Atlantic Ridge at 45°N.
R. C. Lilwall, T. J. G. Francis and I. T. Porter

S6 Ocean Bottom Seismograph Observations Near the Eastern End of the St. Paul's Fracture Zone.
T. J. G. Francis, I. T. Porter and R. C. Lilwall

The Transmission Path

S9 Computed Characteristics of Seismic Surface Waves for Anisotropic Models of Oceanic Structure.
S. Kirkwood

SESSION SII

Chairman: Dr. M. H. Worthington

S2 Seismic Wave Propagation in Anisotropic Media: I. Computations.
S. Crampin

S3 Seismic Wave Propagation in Anisotropic Media: II. Observations.
S. Crampin

S8 A New Approach to Surface Wave Dispersion.
N. J. Kerry and B. L. N. Kennett

S7 The Structure of Seismic Scattered Waves.
J. A. Hudson and J. R. Heritage

S1 Scattering at the 650 km Boundary.
B. J. Barley

S11 Is P_n Velocity an Indicator of Q_α?
P. D. Marshall

SESSION SIII

Instrumentation and Networks

Chairman: Professor T. Murphy

S14 A Seismic Network in Ireland.
A. W. B. Jacob, T. Murphy and G. Wallace

S15 CWF - A Seismic Station in the Midlands.
P. K. H. Maguire

S13 An Experiment with a U.K. Seismological Data Centre.
F. H. Grover

S16 Development of Miniature Wide-Band Force-Balance Seismometers.
M. J. Usher

S17 Recent Developments in Portable Seismograph Equipment.
P. L. Willmore

SESSION SIV

Seismic Risk

Chairman: Mr. A. Douglas

S21 Microzoning in Space and Time.
P. L. Willmore

S19 Seismicity and Associated Risk in the United Kingdom.
P. W. Burton

S18 Induced Seismicity in the United Kingdom.
C. W. A. Browitt

S20 Earthquake Parameters from Extreme Value Statistics.
C. Makropoulos and P. W. Burton

Regional Studies

S22 Seismicity of the South Sandwich Islands Region.
C. P. Brett

S24 Teleseismic Delay Times, Bouguer Anomalies and Inferred Thickness of the African Lithosphere.
J. D. Fairhead

SESSION SV

Chairman: Dr. T. J. G. Francis

S28 Teleseismic Delay Times for Underground Nuclear Explosions to Seismograph Stations in Britain.
A. S. White and J. D. Fairhead

S26 Resonances in Microseismic Noise Spectra.
D. T. Meldrum

S25 Determinations of Q_α for Direct Paths from the Urals to the U.K.
R. W. Hurley

S27 A Surface Wave Study of the Structure of the North Sea and Scandinavia.
G. W. Stuart

S23 Lateral Variations of P Wave Velocity Structure Within the Eurasian Region
P. C. England and M. H. Worthington

4 Abstracts

Abstracts of papers accepted for presentation at the working sessions of the Assembly are presented below. They are grouped under the seven section headings defined in the preface. Reference numbers are prefixed by an initial letter, A, F, G, L, M, P or S defining the section. Subgroups within the larger sections have been defined and are labelled. Within each subgroup, abstracts are presented in alphabetical order of the name of the first author.

GENERAL (INVITED) LECTURES

I 1

PLANETARY ATMOSPHERES AND THE EMERGING PERSPECTIVE

G. E. Hunt, Meteorological Office, Bracknell, Berkshire

There is considerable interest at this time in determining the mechanisms and feedback processes associated with climatic change of the Earth's atmosphere. We do not know whether man's activities may have any effect or whether external effects such as solar activity can modify the climate. But the Earth's weather and climate are complicated by the effects of oceans, continents and mountains. Consequently, it is no longer possible nor desirable to consider the Earth's atmosphere in isolation from other planetary atmospheres.
There are now four planets, Earth, Mars, Venus and Jupiter that have been examined at close range by spacecraft in addition to the studies performed by Earth based instruments and they reveal a considerable diversity in atmospheric phenomena. In this lecture we review our current understanding of planetary atmospheres and discuss the observations that are still necessary to resolve the outstanding meteorological problems, for example Jupiter's Great Red Spot and climatic change on Mars, the super rotation of the upper atmosphere of Venus and the structure and composition of the Titanian atmosphere. In this way we treat the planetary atmospheres of the solar system as natural laboratories to test our understanding of atmospheric phenomena present on the Earth in extended surroundings in order to provide a greater insight into atmospheric systems in general.

I 2

REVERSALS OF THE EARTH'S MAGNETIC FIELD

J.A. Jacobs. Department of Geodesy and Geophysics, University of Cambridge.

This review summarizes the progress in our knowledge of reversals of the Earth's magnetic field since Bullard's Bakerian Lecture to the Royal Society in 1967. Reversals have played a major role in the changed outlook in geological thinking through the development of the concept of plate tectonics. The mean frequency of reversals has also shown marked changes in the past and these may well be related to major tectonic changes. In spite of these increased benefits to the geologist, the physics of the reversal mechanism is still not well understood. The detailed behaviour of the magnetic field during a polarity transition is described as well as the more recently observed phenomenon of excursions of the field. Physical and mechanical models of the geodynamo are examined in some detail in so far as they may affect reversals. The statistical sequence of geomagnetic reversals is also discussed.

I 3

A GEOPHYSICIST'S APPROACH TO THE MOON AND PLANETS

S.K.Runcorn, Institute of Lunar and Planetary Sciences, School of Physics, The University, Newcastle upon Tyne.

The geophysicist, geochemist and planets as bodies to test the theories developed over the last two centuries to explain the global properties of the Earth. Indeed an essential part of the scientific method in geophysics and geology as in othe sciences must be to test the theories outside the field for which they have been developed.

Perhaps the two most profound and difficult theories of geophysics developed in the last generation are the dynamo theory of the generation of the geomagnetic field due to Elsasser and Bullard and the convection theory of continental drift and plate tectonics. Much remains unsolved in both theories, but the new data being obtained by space missions and renewed astronomical observations, both visual and radio, is giving new impetus to theory. Can the present magnetic fields of Mars, Jupiter, Saturn, Mercury and possibly Venus give us any insight into the dynamo process. Does the ancient magnetic field of the Moon inferred from the remanent magnetization of the Apollo rocks and its decrease with time help? Why do all the terrestrial planets and the Moon possess non-hydrostatic low harmonic terms in their figures? Does this imply convection and if so why does the Moon, Mercury and Mars show no sign of continental drift although like the Earth hemispherical asymmetry. Is Venus the other planet with moving plates?

14

MARINE MAGNETIC ANOMALIES

F.J. Vine School of Environmental Sciences, University of East Anglia

Initial interpretations of marine magnetic anomalies concentrated on defining plausible limits for the intensity of magnetisation and geometry of the causative bodies in the crust. With the realisation that the remanent component of magnetisation is dominant and that many of these anomalies could be explained by a combination of sea floor spreading and reversals of the Earth's magnetic field, interest shifted to deducing the evolution of the ocean basins and the times of magnetic reversals during the past 200 m.y.. Such studies reveal that virtually all deep sea floor has been formed by a spreading process with the possible exception of that beneath certain magnetically 'quiet' areas adjacent to passive continental margins. Because of the dominance of remanent magnetisation it has also been possible to deduce palaeolatitudes of formation for older oceanic areas by analysis of the linear anomalies developed over them or the isolated anomalies associated with uniformly magnetised seamounts. More recently there has been a return to consideration of the vertical extent and geometry of magnetisation contrasts in the crust. Measurements on material from ophiolites and drilled samples from layer 2 indicate that a greater thickness of crust is involved than has commonly been assumed. Detailed studies of the way in which the crust is formed, and the phase-shifting of the anomalies produced as a result of a change in latitude and/or orientation both suggest that the boundaries between normally and reversely magnetised crust are sloping rather than vertical but at very different angles at different depths.

APPLIED GEOPHYSICS INCLUDING GLACIOLOGY

A 1

IN SITU SEISMIC MEASUREMENTS OF CRACK ANISOTROPY

D. Bamford, Department of Geophysics, University of Edinburgh
K. Nunn, Department of Geological Sciences, University of Birmingham

The physical properties of rocks, especially their seismic velocity, are controlled to a great extent by cracks and fractures. There are many reasons why such cracks and fractures may have a preferred orientation which should then result in a significant velocity anisotropy. We have applied interpretation techniques developed for the study of anisotropy in the crust and upper mantle to the in situ measurement of possible velocity anisotropy of fractured Carboniferous Limestone in Northwest England, using conventional refraction equipment and a weight-drop source. Compressional wave velocity measurements indicate that velocity anisotropy of 10-20% is present with directions of maximum and minimum velocities that can be directly related to the mapped orientations of joints and fractures. It seems that velocity anisotropy measurements have considerable potential for the assessment of in situ crack and fracture properties.

A 2

THE USE OF GEOPHYSICAL METHODS IN LOCATING BURIED VALLEYS IN N.E. ENGLAND

J.D. Cornwell, E.M. Andrew, Miss C. Johnson and M.K. Lee, Applied Geophysics Unit, Institute of Geological Sciences

Channels formed during the period of the last glaciation in N.E. England were frequently not re-occupied when the river system was restored and exist as drift-filled valleys in a bedrock made up of Middle and Upper Carboniferous sediments. Although the existence of the valleys has been proved in places by boreholes, their form and continuity can be checked efficiently by geophysical methods aimed at determining the depth to bedrock. With examples from the Tyne and Derwent valleys, the use of gravity, seismic and resistivity methods and the interpretation of the results are described.

A 3

3-D DATA COLLECTION AND DISPLAY

M.J.G. Cox and W.R. Cotton, Geophysical Service International, Bedford.

During the last few years several techniques have been introduced into the geophysical industry to collect and process seismic data in 3-dimensions. One of these techniques which utilizes almost equal sampling on the earth's surface in both the x and y directions over the complete prospect will be discussed. The quantity of data collected and processed in this manner, over a given prospect, is an order of magnitude greater than that with conventional techniques. Several ways which can provide the geophysicist with a total interpretive view of his prospect, not biased by anyone's personal judgement, will be presented. Two methods utilizing conventional vertical cross sections and one method where the seismic data is displayed as horizontal cross sections will be shown on data from two prospects.

A 4

A DEEP RESISTIVITY SOUNDING AT ROOKHOPE CO. DURHAM

G.M. Habberjam and C. Thanassoulas Department of Earth Sciences, University of Leeds

An account is given of the technique used to conduct a deep resistivity sounding (up to electrode spacings of 5 km) at Rookhope. Effectively the sounding was crossed and the method of deriving the potential curve to obtain resistivities in conventional Schlumberger terms is described. A measure of the orientational variation of the sounding results is also given. An interpretation of the final sounding curve is discussed in relation to the nearby Rookhope borehole.

A 5

IN-SITU ELECTRICAL AND ACOUSTIC MEASUREMENTS - AN AID TO RAPID GEOTECHNICAL MAPPING ON THE SEA-FLOOR

P.D. Jackson and R. Baria Institute of Geological Sciences, Exhibition Road, London

Electrical resistivity and sound speed measurements have been made on the sea-floor using two geophysical probes which

are both designed to produce minimal disturbance. These measurements have been related to porosity using empirical correlation curves produced on the basis of laboratory analyses. The resistivity probe employs automatic current controllers to focus current into the seabed. The acoustic probe has two transmitters and four receivers which are forced into soft sediments. The maximum depth of investigation varies linearly with the size of each probe and at present is in the range 0.5 - 1.0 m. Good agreement has been found between values of porosity inferred from acoustic and resistivity measurements, made in the Forties Field, and measurements made on cores taken nearby. Also, it has been possible to map changes in sediment type in the Irish Sea using the resistivity probe, the in-situ porosity being controlled largely by the size of the sediment.

A 6

TRANSFORMATION OF MAGNETIC INTO PSEUDO-GRAVITY ANOMALIES USING AN INTERACTIVE GRAPHICS TERMINAL

C.McCann, Dept. of Geology, University of Reading

The "pseudo-gravity" anomaly of a body of uniform density and uniform magnetisation may be computed from the Fourier transform of the total magnetic field anomaly via the magnetostatic and gravity potentials. Generally the direction of magnetisation of the body is not known, but is simply determined as that which gives a one-signed pseudo-gravity anomaly. An interactive BASIC computer program is given for carrying out this procedure The Fourier transform of the magnetic anomaly is input from a file, followed by a sequence of assumed directions of magnetisation from the graphics terminal. For each direction the pseudo-gravity anomaly is computed and plotted on the terminal screen for the user to assess when the anomaly becomes one-signed. Applications of the method to magnetic anomalies over Dartmoor and the Malverns are given. Other fields of application of the interactive graphics terminal in geophysical research and teaching are demonstrated.

A 7

MARINE GEOPHYSICAL SURVEYING IN ENGINEERING STUDIES OF COASTAL ZONES

D.M. McCann Engineering Geology Unit, Institute of Geological Sciences, London
R.A. Floyd Marine Geophysics Unit, Institute of Geological Sciences, Edinburgh

The application of various marine geophysical techniques to engineering studies in coastal and estuarine environments is considered. In the estuary of the River Crouch (South Essex) a continuous seismic profiling survey revealed the presence of a deep buried Pleistocene channel somewhat misaligned with the course of the present day estuary. This information was produced for the preliminary assessment of possible major highway routes across the estuary to the airport on Maplin Sands. In the Lyme Regis/West Bay area in Dorset an appraisal of the engineering characteristics of the near-shore environment was carried out in connection with coastal engineering studies in this area. Seabed morphology was examined using an echo-sounder and sideways looking sonar in conjunction with sampling of the sea-floor sediments and rocks. In the Wash, continuous seismic profiling surveys were carried out to determine the thickness of superficial sediments above the bedrock in an engineering feasibility study into water storage.

A 8

A COMPARISON OF I.P. TRANSIENT SHAPES OVER DISSEMINATED AND MASSIVE SULPHIDE SHEETS IN THE LOWER PILLOW LAVAS OF CYPRUS

G. Maliotis, Hellenic Mining Co., Cyprus
M.A. Khan Department of Geology, The University, Leicester

A number of Time-Domain I.P. traverses were carried out across 2 parallel mineralised sheets in the Lower Pillow Lavas, near Mitsero, Cyprus with Huntec Mark III equipment using the pole-dipole array. In one sheet the mineralisation was disseminated (2% S), and in the other it was massive (30% S). At the n = 2 separation, the transients were recorded at a number of points to give the complete shape of the curves and a number of features compared. The normalised time integrals were anomalous over the two sheets but they were not signif-

icantly different, the highest values being observed over the disseminated sheet. Both sheets were also associated with high electromagnetic components of the decay curve. The chargeability values obtained over the disseminated body were considerably higher. The chargeability/resistivity ratio was also of value in discriminating between massive ore disseminated mineralisation and barren rock. The values of P_2 and P_3 for the two bodies were also compared (P_2 and P_3 being defined by $P_2 = \frac{M_1 - M_3}{M_2}$ and $P_3 = \frac{M_2 - M_4}{M_3}$, where M_1 to M_4 are the amplitudes of the decay curve at the 4 points, 55, 130, 280 and 580 millisecs respectively). For the massive ore, P was inversely related to M but for the disseminated ore, P was independent of M.

A 9

HOLOGRAPHIC MAPPING OF COAL SEAMS USING CHANNEL WAVES

I.M. Mason, Department of Electronics and Electrical Engineering, University College London

D.J. Buchanan, National Coal Board, Mining Research and Development Establishment

It is important, for both economic and safety reasons, to be able to predict the layout of the strata ahead of advancing coal faces. A number of different physical methods have been proposed but, to obtain the required resolution and long-term prediction, it appears that underground seismology at the coal face must be practised. It has been shown that the acoustic impedance contrast of coal compared with the surrounding strata results in a channelling of seismic waves within the coal seam. This means that if a seismic source is placed within a seam then a considerable proportion of the energy is restricted to the seam, thereby increasing the probability of detecting reflected waves from any in-seam discontinuity such as a geological fault or old water-filled workings. One disadvantage, however, is that the waves are dispersive and this must be taken into account in the subsequent data processing.

We have conducted both laboratory and underground experiments. In the latter case, explosive sources have been used and the recording system was specially designed for use in an underground environment. The coal seams examined to date are sufficiently homogeneous to enable numerical holographic techniques to be used in data processing. The configuration of scatterers or sources can be deduced by compressing the signals in time and space, and then constructing the maps interactively on a mini-computer. These methods will be discussed more fully in the talk.

A10

A SHALLOW LAND SEISMIC REFLECTION SYSTEM USING A VIBRATOR SOURCE

E.G. Webb and K.R. Nunn
Department of Geological Sciences
University of Birmingham

The development is described of an experimental shallow seismic reflection system for the depth range 10-60m. The system uses an electromagnetic vibrator as a source and a digital averager for stacking and digitisation of records prior to recording on magnetic tape. Field techniques and processing techniques so far tried are described. Processing includes deconvolution for pulse compression and velocity filtering. The system has been field tested on several sites in the U.K.

A11

JOINT MODELLING OF GRAVITY AND MAGNETIC ANOMALIES USING NON-LINEAR OPTIMISATION

G.K. Westbrook Department of Geological Sciences, University of Durham.

A technique is presented in which structures producing gravity anomalies and magnetic anomalies are modelled simultaneously to produce an optimal fit of the calculated gravity and magnetic anomalies to the observed anomalies. To achieve this a function embodying the squares of the residuals of the gravity and magnetic anomalies is minimised using iterative techniques such as the Simplex method of Nelder and Mead, and the Davidon variable matrix algorithm. It is particularly effective when only parts of any structure produce a magn-

etic anomaly, and when various bounds and constraints are placed on the model. Examples of the technique applied to theoretical models and real cases are discussed.

A12

A BOREHOLE CONTROLLED SOURCE INDUCTION PROCEDURE FOR THE DETERMINATION OF ELECTRICAL CONDUCTIVITY STRUCTURE

M.H. Worthington Department of Geology and Mineralogy, Parks Road, Oxford.
A.R. Kuckes Department of Physics, University of Cornell, U.S.A.

Electrical conductivity values have been obtained for structure away from the immediate vicinity of a borehole. This is achieved by using a horizontal loop induction source on the surface and borehole horizontal and vertical magnetometers and gradiometers. Signals from the borehole receivers and a reference from the source are supplied to a lock-in amplifier and amplitude and phase variations of the magnetic field with depth are determined. Conductivity estimates are achieved by numerical modelling assuming a plane layered structure. Information on lateral variations of structure is also obtained.

A13

SURFACE STRAIN RATE MEASUREMENTS ON SEA-ICE AND GLACIERS.

D.J. Goodman, Physics and Chemistry of Solids Group, Cavendish Laboratory, University of Cambridge.

Results of a three year programme to develop the use of geophysical wire strainmeters to measure surface strain rates on glaciers and sea ice will be presented. Improvements in the technique will be outlined in the light of field trials carried out in Greenland, the Barnes Ice Cap, Baffin Island, and sea ice in Labrador (the details of which will be published elsewhere). A new instrument, which uses a 1 m Invar bar as a length standard, will be described. It is shown that the technique can either detect the directions and magnitudes of the principal strain rate axes on the surface of a glacier if these are greater than 10^{-7} strain per day or the directions and magnitudes of strains produces by the action of sea waves on sea ice. Future applications are outlined.

A14

RADAR TECHNIQUES IN GLACIOLOGY AND OTHER FIELDS - A REVIEW

D T Meldrum, Scott Polar Research Institute, University of Cambridge

Radar sounding of ice and snow has become established as a major tool in the investigation of sub-ice geology, ice dynamics and ice physics; and is being further developed to encompass applications in sea ice studies and in the sounding of ice-free areas. A review is given of the techniques currently in use, their applications and limitations, and future developments are discussed with reference to possibly more general geophysical studies.

A15

THE RADIO FREQUENCY BI-PEFRINGENCE OF POLAR ICE SHEETS

N D Hargreaves, Scott Polar Research Institute, University of Cambridge

Radio-echo sounding of polar ice sheets has shown that they are bi-refringent at radio frequencies. The optical bi-refringence of ice is well established, and a discussion is given of the expected level of electrical anisotropy of a single ice crystal at radio frequencies. Polar ice sheets are polycrystalline, with preferred orientations of the ice crystals determined by the strain field of the ice sheet. A theoretical treatment is derived which may be used to obtain the effective bulk dielectric tensor of polycrystalline ice. A comparison is then made between the observed and expected levels of radio frequency bi-refringence.

MAGNETOHYDRODYNAMICS AND METEOROLOGY

F 1

MAGNETOHYDRODYNAMIC WAVE ENERGY FLUX

J.A. Adam, Department of Applied Mathematics, University of St. Andrews

Results are presented concerning the stability of certain magnetoatmospheric systems (in which the restoring forces of buoyancy, compressibility and magnetic fields are important) in the presence of shear. The basic linearised equations enable a convenient description to be made of the behaviour of the net upward energy flux in such a system. From a detailed consideration of the energy flux function a number of results are established, including the extension of the well-known semicircle theorem to shear along a horizontal magnetic field in a stratified compressible atmosphere. This places an upper bound on the range of the complex phase velocity of unstable modes. It is also shown that purely convective modes ($Re(\omega) = 0$) do not in general exist. A sufficient condition is given for stability, which is not necessarily limited to the case of convectively stable atmospheres, and this is compared with those derived on the basis of the energy method. The behaviour of the energy flux function in convectively stable regions is also discussed.

F 2

THE SPECTRUM OF LEE WAVES IN STRATIFIED FLOWS

F.H. Berkshire, Department of Mathematics, Imperial College, London

Linear lee wave theory has demonstrated how significant stationary gravity waves, produced by the flow of a density - stratified fluid over an obstacle, can appear in the form of a discrete spectrum of modes with real wavenumber and with amplitude decaying with height. Here it is indicated how the continuous spectrum of wavenumbers which give internal waves at all heights may often be assessed in terms of complex 'modes' which have decaying amplitude in the downstream direction. For a given obstacle these waves may dominate the real modes - if the latter are present - and may produce an important contribution to the drag produced by the obstacle on the flow. In the atmosphere the effect of such drag may be apparent at great heights.

F 3

GENERATION OF MAGNETIC FIELDS BY FLUID MOTIONS OF GLOBAL SCALE

David Gubbins, Department of Geodesy & Geophysics, University of Cambridge.

There are many examples of fluid motions that give kinematic dynamos in an infinite medium, but very few cases of dynamos in an electrical conductor of bounded extent. This curious observation is investigated by numerical calculation. Two significant effects are revealed. An insulating boundary is found to cause a current sheet to form near it and this inhibits magnetic field generation. Also the ratio of poloidal to toroidal component of fluid flow must lie in a certain range for dynamo action to occur, because otherwise the diffusive effects of the separate components dominate the regeneration mechanism which requires a combination of both. These two effects help account for some of the difficulties encountered in constructing kinematic dynamo models, and are relevant to the problem of generation of magnetic field by thermal convection in a rotating system.

F 4

THE OBSERVED FLUX OF POTENTIAL VORTICITY IN THE STRATOSPHERE

R.S. Harwood Department of Meteorology, University of Edinburgh

Because it is possible to obtain the poleward flux of momentum from a knowledge of the fluxes of heat and potential vorticity, it is important in constructing 2-dimensional models of the atmosphere to know to what extent the flux of potential vorticity can be parameterised. This paper presents some observations of potential vorticity fluxes in the mid-stratosphere and seeks to relate them to the zonal mean distribution. In particular it is shown that there is not always a simple down-gradient transport anticipated by several two-dimensional models.

F 5

THE TRANSPORT OF OZONE IN A TIME-DEPENDENT, TWO-DIMENSIONAL MODEL

R.S. Harwood* and J.A. Pyle, Department of Atmospheric Physics, Oxford University

A two-dimensional, time dependent numerical model of the atmosphere has been used to investigate the ozone budget. The photochemistry includes catalytic destruction of ozone by the oxides of hydrogen and nitrogen with the source and sink terms linearized about the equilibrium values. The behaviour of the modelled ozone is quite satisfactory especially in low and mid-latitudes. Many of the observed details have been reproduced including hemispheric asymmetries of the total ozone amounts. Photochemical production in the model takes place in the mid stratosphere in low latitudes with destruction in the high latitudes of both hemispheres. The mean motion fluxes are the most important transport term in equatorial latitudes. Polewards the eddies become relatively more important. In middle and high latitudes there is near cancellation between mean and eddy flux divergences. The hemispheric asymmetry in the total ozone amount results in part from the high latitude mean circulation driven by the eddy fluxes of angular momentum. Tropospheric processes also are responsible for some differences between the hemispheres. Attention is drawn to the difficulty of describing the vertical transports in a one-dimensional model.

* Now at Department of Meteorology, University of Edinburgh.

F 6

THERMAL CONVECTION IN A ROTATING FLUID SUBJECT TO A HORIZONTAL TEMPERATURE GRADIENT: SPATIAL AND TEMPORAL CHARACTERISTICS OF FULLY DEVELOPED BAROCLINIC WAVES

R. Hide, P. J. Mason and R. A. Plumb, Geophysical Fluid Dynamics Laboratory, Meterological Office, Bracknell, Berkshire

Detailed studies of the azimuthal structure of fully developed waves in a differentially-heated rotating fluid annulus have been carried out with the aid of instrumentation capable of providing frequent determinations of the temperature variation around a circle concentric with the walls of the annulus. The time-averaged azimuthal spectra thus obtained show that in the regular regime, where the flow is dominated by a single Fourier mode of wavenumber M (say), significant "energy" is found not only in the harmonics, which describe the jet stream structure of the flow, but also in the side-band modes of wavenumber M $\pm$ 1, which describe the observed azimuthal modulations in the amplitude and/or phase of the wave. At the high-wavenumber end of those spectra for which an inertial sub-range can be resolved, the "spectral energy" follows a "wavelength cubed" law. The time-dependent behaviour of the phases of the side-bands and the main baroclinic mode is such that a special frame of reference can be found in which the instrinsic frequencies of the modes are equal. These results can be interpreted with the aid of simple wave-interaction theory, which suggests that the side-bands interact strongly with baroclinically-stable long waves, but in such a way that in equilibrium the net transfer into the long waves is small.

F 7

ON DETACHED SHEAR LAYERS AND WESTERN BOUNDARY CURRENTS IN A ROTATING HOMOGENEOUS LIQUID

L.M. Hocking, Department of Applied Mathematics, University College London
R. Hide, Geophysical Fluid Dynamics Laboratory, Meterological Office, Bracknell, Berks.

This paper reports a combined experimental and theoretical study of slow motions produced mechanically in a rapidly rotating homogeneous liquid by the differential rotation of the rigid walls of the container when the side-wall is a circular cylinder of radius b′, one of the two plane end-walls is inclined at an angle $\Pi/2 - \alpha$ to the axis of the cylinder (which is also the axis of basic rotation with angular speed Ω) and the other end wall is perpendicular to the rotation axis and is split at a distance a from the axis so that the inner part of the end wall can be rotated with relative angular speed Ω. The investiation thus extends to cases when $\alpha \neq 0$ and $a \neq b'$ extensive previous studies of detached shear layers in systems having $\alpha = 0$ and $a \neq b'$ and of western boundary currents in systems having $\alpha = 0$ and $a = b'$ (sliced - cylinder). A full account of the experiments, which cover-

ed a wide range of Rossby number $|\epsilon|$ and Ekman number $E \equiv \nu/\Omega a^2$ (where ν is the coefficient of kinematical viscosity) will be deferred until a numerical study of the non-linear governing equations has been completed. The experiments led to the analytical study of the linear case when $|\epsilon| = 0$ discussed in the present paper. Thus study shows how the general flow pattern changes as α increases, revealing three flow regimes typified by the limiting cases $\tan\alpha << E^{1/2}$, $E^{1/2} << \tan\alpha << E^{1/4}$ and $\tan\alpha >> E^{1/4}$. It also provides some information on non-linear effects, including the magnitude of $|\epsilon|$ at which linear theory should break down in each flow regime and the relative importance of non-linear effects in different parts of the flow.

F 8

A STUDY OF THE STRATIFICATION IN THE EARTH'S OUTER CORE

T.G. Masters. Department of Geodesy and Geophysics, University of Cambridge.

The inversion theory of Backus and Gilbert is applied to the determination of the stratification in the outer core. Various measures of the stratification have been considered, the most satisfactory, for numerical purposes, being Bullen's η which has been determined using seismic data. In view of recent results, the effect of dissipation on the inversion of modal data is investigated with particular emphasis on the anelasticity of the inner core. Implications of the results for the thermal and chemical state of the outer core are discussed.

F 9

HYDROMAGNETIC EFFECTS NEAR A BUMPY CORE-MANTLE INTERFACE

H.K. Moffatt Department of Mathematics, University of Bristol.

Flow over bumps at the core-mantle interface in the presence of a predominantly toroidal magnetic field leads to magnetic field perturbations which are correlated (with a phase-shift in longitude) with the gravitational perturbations caused by the same bumps (Moffatt & Dillon 1976, Phys.Earth Planet. Inter., 13, 67-78). The flow is characterised by three wave modes, two of which have a boundary-layer character, the third being a diffusion mode which penetrates well into the core. The presence of the bumps can lead to an increase in the tangential stress exerted by the core on the mantle and so to an increase in the rate of transfer of angular momentum from core to mantle. Estimates of these effects will be given in terms of the mean bump amplitude.

F10

PROGNOSIS OF OZONOLYTIC POLLUTION

R.S. Scorer, Dept. of Mathematics, Imperial College.

Predictions of effects of NO_x and Cl on stratospheric O_3 using 1D models are misleading for aircraft exhaust and photochemically released Cl. Dilution mechanics and secondary photochemical and dynamical effects are omitted and influence of natural levels underestimated. The prospects of obtaining an adequately parameterised 3D model are negligible and we have to learn to live with ignorance. There are good reasons for ignoring the scares raised by the 1D model, whose predictions can never be tested. Machinery of many governments is too unsophisticated to handle this situation.

F11

NON-LINEAR BAROCLINIC DISTURBANCES TO MID-LATITUDE ZONAL FLOWS

A.J. Simmons and B.J. Hoskins Department of Geophysics, University of Reading

A series of numerical simulations of atmospheric behaviour has been made using as idealized initial conditions zonal jets given small-amplitude perturbations of normal-mode form. Disturbances subsequently grow by baroclinic instability, and display frontal formation and occlusion in agreement with both simpler theoretical models and synoptic experience. As baroclinic growth ceases they become decoupled in the vertical, and decay barotropically, strengthening the upper-level zonal flow. Eddy heat and momentum fluxes averaged over the whole life cycle of disturbances differ significantly from those suggested by linear stability analysis, and exhibit much more variation with zonal wavenumber

then with the flow profile. The dominant eddy transfers are in good agreement with atmospheric statistics.

F12

CONVECTION IN RAPIDLY ROTATING FLUID SPHERES

A.M. Soward Department of Applied Mathematics, University of Newcastle upon Tyne

The onset of instability for a self-gravitating, internally heated, fluid sphere of radius r_o at large Taylor number, T, is investigated. According to approximate linear theory it is well known that convection sets in first as overstability and that the ensuing motion corresponds to the Eastward propagation of Rossby waves, which have a short wave length of order $T^{-1/6}r_o$. These waves are concentrated close to a cylindrical surface, S, coaxial with the diameter of the sphere parallel to the angular velocity. The above theory is revised and new results are obtained for the particular case, in which the Rayleigh number, R, exceeds its critical value, R_c, by an amount of order $T^{-1/3}R_c$. the linear theory predicts that conditions for convection are favourable in a layer of width $T^{-1/18}r_c$ about the surface, S. Here according to non-linear theory, Rossby waves propagate steadily within distinct sublayers of width $T^{-1/3}r_o$, which, in general, drift slowly across the $T^{-1/18}$-convection layer.

F13

INTERNAL GRAVITY WAVES IN A SHEAR FLOW

S.A. Thorpe, Institute of Oceanographic Sciences, Godalming

The presence of a current which varies with depth in the ocean (or a model atmosphere) modifies the structure and speeds of possible internal gravity waves. We describe a non-linear, normal mode, analysis with numerical results being obtained for a fluid with a single (not necessarily narrow) thermocline at which the shear is concentrated. These conditions are easily produced in the laboratory, and experimental results are presented which demonstrate, in particular, the breaking of internal waves (in a cine film).

F14

ASPECTS OF GEOPHYSICAL TURBULENCE

J.D. Woods Institut für Meereskunde an der Universität Kiel

The motion on all scales from millimetres to megametres in the atmosphere and ocean appears to be turbulent. The aim of this paper will be to examine some of the statistical properties of this turbulence, taking into account the effects of stratification (large Richardson number), rotation (low Rossby number) and the Earth's curvature (β effect). A preliminary attempt is made to derive the form of the climatological distribution of turbulent kinetic energy in the four Fourier dimensions (i.e. meridional, zonal and vertical wavenumbers and frequency) from (a) observations and (b) classical turbulence hypotheses concerning the cascade of energy through the spectrum. In order to achieve this it is necessary to introduce assumptions concerning the relationship between the local properties of the flow and the mean statistics, and concerning the definition of frequency.

GEOMAGNETISM

General

G 1

DOES THE GEOMAGNETIC FIELD HAVE A SIGNIFICANT MONOPOLE COMPONENT ?

D.R. Barraclough. Geomagnetism Unit, Institute of Geological Sciences.

The zero degree and order term (g_0^0) of a spherical harmonic model of the geomagnetic field could, if significantly different from zero, be interpreted as arising from monopolar sources. Extensive data sets for 3 epochs have been analysed so as to include the g_0^0 term, whose significance is discussed. The time changes of the 'monopole' coefficient over a period of 30 years have also been studied using a homogeneous series of observatory data.

G 2

A DEFINITIVE MODEL OF THE GEOMAGNETIC FIELD FOR EPOCH 1975

D.R. Barraclough, J.M. Harwood, B.R. Leaton and S.R.C. Malin. Geomagnetism Unit, Institute of Geological Sciences.

A spherical harmonic model of the main geomagnetic field and its secular variation has been derived, to degree and order 8, using all available data from the period 1955 to 1975. This definitive model is compared with the original International Geomagnetic Reference Field (IGRF 1965). The new model is extrapolated down to the core - mantle interface and the significance of the extrapolated coefficients is discussed. Various physical features associated with the model are also investigated.

G 3

SYNTHETIC PLOTS OBTAINED FROM AN OSCILLATING ALLDREDGE-HURWITZ RADIAL DIPOLE MODEL

K.M. Creer and T.E. Hogg, Department of Geophysics, University of Edinburgh

Attempts have been made to simulate long period secular variations using an oscillating eccentric radial dipole model. This model allows eight radial dipoles as positioned by Alldredge and Hurwitz (1964) to oscillate as a sine function. The period and phase of the oscillations can be varied for each dipole, as can their strength and radial distance. The field at any point on the earth's surface is then calculated by summing the effect of each dipole over even intervals of time. The synthetic curves so obtained are compared with curves derived from cores of Holocene sediments. The effect of varying the different parameters will be shown and the characteristics of simulated geomagnetic excursions will be described.

G 4

THE (IN) SIGNIFICANCE OF THE CORRELATION BETWEEN THE EARTH'S GRAVITATIONAL AND MAGNETIC FIELDS

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It is argued that the most relevant radius at which to perform the correlation is that of the core-mantle interface, and that the physically most relevant quantities are the gravitational potential (which reflects the 'bumps') and the magnetic vertical intensity (i.e. the flux leaving the core). The maximum correlation is then only 0.583, with a probability of this occurring by chance of 28%, compared with the usually quoted values of 0.837 and 2.4% for the magnetic potential at the Earth's surface.

G 5

A LAYMAN LOOKS AT DYNAMO THEORY

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It is now well established that dynamo action will occur if the fluid motion in the core is 'sufficiently' vigorous and 'sufficiently' asymmetric, and it is not unreasonable that sufficient power is available from heat sources in the core. But as yet dynamo theory provides only very weak constraints on the necessary core size/fluid velocity/speed of rotation, cannot explain the relative magnitude of the dipole and non-dipole fields or why the dipole magnitude remains so constant over geological time, and is not able to predict the reversal spectrum.

G50

A GEOMAGNETIC TEST OF MAXWELL'S EQUATIONS

R.L. Wilson, C.R. Johnson, A.G. MacCormack and D.R. Barraclough. Department of Geophysics, University of Liverpool.

Einstein's unified field theory predicts that, for a sufficiently large-scale experiment, deviations from Maxwell's equations should become apparent. In particular, a toroidal field, and a poloidal field with a curl, both become possible even in non-conducting regions like the earth's atmosphere. We have analyzed the geomagnetic field for such phenomena. If they exist, they lie in fields of order 10 gamma or less, for the case of the earth.

Induction

G 6

EFFECT OF CONDUCTIVITY ANOMALIES IN DEVON ON MICROPULSATIONS.

C. C. F. Adcock, A. M. Hart, C. D. Honebon and W. G. V. Rosser.

The ratios of the North-South (H) components of the magnetic fields of micropulsations of period 20 to 150 s at stations in the vicinity of Exeter to the values at Sidmouth is approximately 1.4. This difference must be due to electric current flowing beneath some of the stations. The vertical (Z) components show a complicated variation between stations. For example, Z reverses direction between Exeter and Bickleigh Castle, which is 10 km North of Exeter. At Sidmouth Z is complicated by the English Channel. The probable causes of these differences are (1) diversion of current by the Dartmoor granite, (2) the Crediton Trough, a small rift valley running East-West just North of Exeter (3) the English Channel.

G 7

THE REPRESENTATION OF INTERNAL FIELDS BY EQUIVALENT CURRENTS IN THIN SHEETS: APPLICATION TO GDS ARRAY STUDIES IN KENYA

R.J.Banks and D.Beamish Department of Environmental Sciences, University of Lancaster

The results of Geomagnetic Deep Sounding investigations can be reduced to maps of the internal fields produced by regional current flow at selected azimuths, by predicting the response from inter-station transfer functions. The internal field maps can be replaced by equivalent currents in a thin sheet at some selected depth. In the wavenumber domain, the current system is obtained by the use of a downward continuation filter. We use this technique to generate internal current maps from the results of an array study of the Kenya Rift Valley.

G 8

LOCAL CONDUCTIVITY EFFECTS ON THE MAGNETIC FIELDS DUE TO SEA TIDES

A. M. Hart, Department of Physics, University of Exeter.

Measurements of the 12.42 lunar variation in the North-South (H) and vertical (Z) components of the geomagnetic field at a coastal site (Sidmouth), and a site 10 km inland (Exeter) have been made using two rubidium vapour magnetometers in a gradiometer configuration. For the vertical component, the difference between the sites is one third of the value at Exeter. For H, the difference is about the same as the total variation at Sidmouth. Such differences are attributed primarily to electric currents flowing in the land, and are thus subject to local conductivity anomalies.

G 9

FIRST ORDER SOLUTIONS OF OCEANIC INDUCTION PROBLEMS

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P. C. Kendall, Department of Mathematics University of Keele, Staffs ST5 5BG

A model ocean is considered on a globe with a perfectly conducting, smaller, concentric globe beneath. This model is immersed in an oscillating external e.m. field. We show how to calculate the magnetic flux passing beneath the ocean, to the first order, for variations of period $\leq$ 12h (say). Analytic solutions can be readily obtained for simple geometries such as the well known spherical cap. These first order solutions are satisfactory when compared

with "exact" spherical harmonic solutions. The method can be used to provide boundary conditions for strip problems which simulate local edge effect problems.

G10

THE ELECTRICAL CONDUCTIVITY OF THE MOON: AN APPLICATION OF INVERSE THEORY

B.A. Hobbs, Department of Geophysics, University of Edinburgh

Inverse theory of Backus and Gilbert is used to analyse the day-side electromagnetic response of the moon to magnetic fluctuations in the solar wind. The data consist of two transfer functions, both tangential to the lunar surface, and in the theoretical development, the required Frechet derivatives corresponding to these transfer functions are determined. The ensuing calculations show that the data are sufficiently good to determine the conductivity down to a depth of about 600 km. The results are very encouraging and it is suggested that as newer theories of lunar induction are developed to consistently interpret the day- and night-side measurements, they should be used in the above enlightened manner.

G11

THE INTERPRETATION OF GEOMAGNETIC VARIATION OBSERVATIONS IN SCOTLAND USING THE HYPOTHETICAL EVENT TECHNIQUE

V.R.S. Hutton, J. Sik, A.G. Jones and D. Rooney, Department of Geophysics, University of Edinburgh

Since 1973, a continuing programme of geomagnetic induction studies has been undertaken in Scotland. For time variations of period > 10 min, it has comprised the simultaneous operation of 20 3-component magnetometers in each of N. and S. Scotland and subsequent single station and small array geomagnetic recording; for shorter period phenomena, T > 10 s, observations have also been made at 13 locations traversing the southern uplands. In this paper, the results of the various studies are synthesised using the hypothetical event technique proposed by Bailey et al. (1974). The interpretation which follows is compared with other methods of presentation of geomagnetic induction data. For S. Scotland, the manner in which it complements the M-T analysis (Jones and Hutton, 1977) is discussed.

G12

A METHOD FOR THE PROCESSING OF MAGNETOTELLURIC DATA

Alan G. Jones, Department of Geophysics, University of Edinburgh

In the analysis of recent magnetotelluric observations from the southern uplands of Scotland, more high frequency information has been extracted than is possible using standard techniques. The method involves dividing the data segment into sub-sets of the required length and computing frequency domain parameters for each sub-set. This represents a frequency domain version of the sonogram analysis of Swift (1967) and Hermance (1973) but, in execution, it results in much less effort and computer time. Also new forms of coherence functions are defined - these are more practical than the standard forms when constant Q or logarithmic windows are applied to the data. Examples of the applications of these techniques to the Scottish M-T data are presented.

G13

A COMMENT ON METHODS OF SOLUTION OF OCEANIC INDUCTION PROBLEMS

P.C.Kendall, Department of Mathematics, University of Keele, Staffs ST5 5BG

Recently, Hobbs and Brignall claim to have significantly modified the method of shifting the spectrum. They imply that this has somehow rendered the oceanic induction problem more convergent. In fact, the convergence rate is the same as for the method of shifting the spectrum; and this was to be expected, as the method is in fact the same. The convergence of all methods is poor for micropulsation periods, but it is reasonable for the daily variations. Nevertheless, calculations have been carried out for high frequencies, and the iterations do in fact converge in a practical sense.

G14

LUNAR GEOMAGNETIC TIDES AND THE OCEAN DYNAMO

D. M. Schlapp, Department of Physics, University of Exeter.

Some preliminary results of the lunar tide analysis of long series of

geomagnetic data are presented. The M_2 tide at midnight is found to show a seasonal variation at certain stations. After consideration of possible complications due to the O_1 tide, it is concluded that the source of the night-time geomagnetic tide must be at least partly external in origin as well as oceanic.

Palaeomagnetism

G15

CHEMICAL DEMAGNETISATION STUDIES OF THE ALDERNEY SANDSTONE, CHANNEL ISLANDS

Jacqueline A. Banner and Ernest A. Hailwood, Oceanography Department, University of Southampton

An investigation into the use of acid leaching for demagnetisation (with particular reference to the Alderney Sandstone) is presented. The effect of the following conditions on the leaching process has been studied:- orientation, field-free space, acid strength, temperature, rock type. In these experiments acid leaching resulted in greater intensity and direction changes than A.F. demagnetisation, but a stable direction of magnetisation could not be isolated for all samples. A period of 200 hours appeared to be critical, since after this time there was a significant decrease in the rate of decay of NRM the total amount of iron leached out approached 100% available iron, and stable directions of remanence were recovered in some cases. The remanent magnetisation measured is used to define a palaeopole position which corresponds closely with a recently published Devonian pole for Normandy and Brittany (van der Voo, 1976) and with the mean Devonian pole position for North West Europe.

G16

EXPERIMENTS RELATING TO FUNDAMENTAL PROBLEMS IN ARCHAEOMAGNETIC FIELD STRENGTH MEASUREMENTS

M. F. Barbetti, K. P. Flude and J. M. W. Fox. Research Laboratory for Archaeology, Oxford University

To investigate the distorting field produced within pottery samples clay rings were fired in reconstructed archaeological kilns, one having a reducing atmosphere and the other an oxidizing atmosphere. This was in cooperation with Peter Reynolds of the Butser Ancient Farm Project. Significant distortions of remanent direction were observed and their implication for archaeointensity measurements are discussed.

Laboratory experiments designed to produce the weathering effects found in magnetic samples have also been undertaken. The specimens were placed for periods up to 3 months in a digestion bomb with distilled water under pressure at approximately 120°C.

G17

POLARITY SEQUENCE OF MULL

P.Dagley and A.E.Mussett, Sub-department of Geophysics, University of Liverpool

On present evidence the magnetic polarity sequence is: all plateau lavas are reversely magnetised, as are the earliest members of the first centre. The rest of the central complex is normally magnetised but dykes which post-date it are reverse.

This sequence and the significance of the Fishnish dykes are discussed.

G18

PALAEOZOIC PALAEOMAGNETIC RESULTS FROM JERSEY, C.I.

B.A. Duff, Department of Earth Sciences, University of Leeds

Palaeomagnetic results have been obtained from a range of lower Palaeozoic rocks from Jersey, relating to the late Precambrian/Cambrian Cadomian Orogeny. Systematic variations of stable NRM in diorites stoped by granite are attributed to blocking of PTRM during cauldron subsidence and rotation. Three late-orogenic granites (c. 570-490 m.y.), unconformably overlying red shales (probably Cambrian), and lamprophyre dykes, all yield pole positions at variance with the lower Palaeozoic polar wander curve for Great Britain, and are interpreted in terms of rapid Cambrian polar wandering relative to Jersey and adjacent regions. Of three groups of palaeomagnetic directions in

crosscutting dolerite dykes, two are consistent with Ordovician/Silurian and Carboniferous data from Britain.

G19

A NEW METHOD FOR DETERMINING THE MAGNITUDE OF THE EARTH'S MAGNETIC FIELD USING SUN-DRIED BRICKS

K.P. Games, Sub-department of Geophysics Liverpool University

A new method of determining the magnitude of the Earth's magnetic field using sun-dried bricks is outlined, and some of the magnetic properties of these bricks are described. The method has been tested on a modern adobe brick from Lima and was found to be accurate and repeatable. Results of palaeomagnitude from Peruvian bricks are presented and compared with palaeomagnitudes obtained from Ceramics. Some preliminary results from Egyptian bricks are also given.

G20

GEOMAGNETIC ARCHAEOMAGNITUDE MEASUREMENTS FROM PERUVIAN CERAMICS

N.M. Gunn, Sub-department of Geophysics, Liverpool University

The application of Shaw's Method to archaeological ceramics is briefly explained, with reference to its advantages in certain respects over thermal demagnetisation methods. The two major obstacles of multiple remanence and thermal instability in the specimens are mentioned, together with an account of their relative prevalence among different types of pottery shards. For the fraction of specimens passing all tests, the field magnitude results are presented on a diagram plotted against time. A provisional assessment of the data is offered, including comparison of the general trend observed here with results from other sources, and some comment on the reality of possibly short-term fluctuations in field magnitude.

G21

MESOZOIC GEOMAGNETIC FIELD CONFIGURATION AND CIRCUM-ATLANTIC CONTINENTAL RECONSTRUCTIONS

E. A. Hailwood, Department of Oceanography, University of Southampton.

Existing palaeomagnetic data from the four circum-Atlantic continents (Africa, South America, North America and W. Europe) will be used to explore the validity of different Mesozoic predrift reconstructions and possible geomagnetic field configurations. In particular an attempt will be made to investigate the extent to which an offset dipole geomagnetic field model might apply to Mesozoic times. Palaeomagnetic pole positions for the above continents have been recalculated on the basis of a dipole source, offset r km northwards along the geographic axis, and the dispersion of poles from the four continents examined as a function of r, for different continental reconstructions. In the case of the South Atlantic it will be demonstrated that available Mesozoic palaeomagnetic data are more consistent with a centred dipole than an offset dipole field source, but that currently accepted reconstructions of the pre-drift positions of South America and Africa in Mesozoic times may require substantial modification.

G22

QUATERNARY PALAEOMAGNETIC RESULTS FROM DSDP SITES 379 AND 380 IN THE BLACK SEA

E. A. Hailwood, Department of Oceanography, University of Southampton
N. Hamilton, Department of Geology, University of Southampton

Preliminary palaeomagnetic studies on a closely-spaced series of samples from a 6 metre section of rhythmically banded sediment at a depth of 800 metres sub-bottom at DSDP site 380A, have revealed the presence of a stable reversed component of magnetisation overprinted by a less-stable normal component. A cyclical change in inclination of the stable reversed component may be interpreted as a record of palaeo-secular variation of the geomagnetic field during the Matuyama epoch. Additional palaeomagnetic information from more-widely spaced samples at Site 380A and 379 provide constraints on the possible location of the Brunhes-Matuyama epoch boundary within the Black Sea sedimentary sequence, and demonstrate the potential value of magnetic polarity stratigraphy for dating DSDP sediment cores.

G23

MAGNETIC FABRIC OF MARINE SEDIMENTS

N. Hamilton Department of Geology, University of Southampton

Variability in magnetic grain fabric style of clastic marine sediments reflects the conditions of sediment accumulation and subsequent deformation. Detailed studies of the magnetic fabric of Tyrrhenian Sea sediments of Holocene age are used to demonstrate the usefulness of this magnetic property for sedimentological investigations.

G24

LATE NEOGENE MAGNETIC STRATIGRAPHY EVIDENCE FROM DSDP MEDITERRANEAN SEA SITES 372, 374 AND 376

N. Hamilton Department of Geology, University of Southampton
E.A. Hailwood Department of Oceanography, University of Southampton

Detailed biozonation of sedimentary sequences recovered during deep sea drilling on Leg 42A in the Mediterranean Sea provide a unique opportunity to correlate observed magnetic polarity sequences with an established geomagnetic time scale. Implications of such tentative correlations, their palaeomagnetic reliability and possible ambiguities are discussed. This provisional magnetic chronology is used in defining the duration of the 'Messinian' evaporitic phase within the Mediterranean.

G25

SECULAR VARIATIONS OBTAINED FROM FRENCH AND SWISS LAKES 0-6000 YEARS B.P.

T.E. Hogg, Department of Geophysics, University of Edinburgh

Results from 6 m 'Mackereth' cores from Lakes Geneva, Bourget, Morat and Annecy covering the period 0-6000 years B.P. are presented. Variations in inclination cover one cycle and correlate well between lakes. Variations in the declination record show one and a half to two cycles in this time interval and correlation between lakes is more difficult. Intensity and susceptibility measurements correlate well in each lake. These records are compared with those from Lake Windermere and some problems arising from attempts at correlation will be discussed.

G26

CONTINENTAL DRIFT BETWEEN THE PALAEOZOIC AND MESOZOIC

E.Irving Earth Physics Branch, Energy Mines and Resources, Ottawa, Canada

Palaeomagnetic result for the Lower Jurassic (175 m.y.) fit Pangaea very well. Upper-Carboniferous to Mid-Triassic (300-215 Ma) do not and systemmatic polar discrepancies of up to 15° occur. Maps have been prepared that account for these descrepancies by rearranging the continents without the creation of intervening oceans. Their main features are the occurrence of about 3000 km of dextral shear along the Hercynian-Appalachian foldbelt, and about 1000km of shear (XM) between Eurasia and North America between the middle Permian and Late Triassic (250-200 Ma). The maps are based on a new global synthesis of the palaeomagnetic data which, for the first time, have been reduced to a uniform time basis. It is suggested that the absence of ocean ridges may account for the world-wide regression at the beginning of the Mesozoic which may in turn have caused whole-sale extinctions. The shear XM may provide a useful kinematic framework within which to discuss the origin of oil-bearing rift structures of the North Sea.

G27

PALAEOMAGNETIC INVESTIGATIONS OF TERTIARY VOLCANIC ACTIVITY IN LOWER SILESIA, POLAND

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The Lower Silesian basaltic rocks form the eastern boundary zone of the central European Tertiary volcanic province. They occur in two groups, along the Odra Fault and along the Sudetic Boundary Fault. The magnetic fraction of the investigated rocks comprises titano-

magnetites containing from 0% to 80% approximately of ulvospinel, oxidized to different degrees. In some exposures oxidation processes have taken place at high temperatures while in other exposures low temperature oxidation to a non-stoichiometric phase is evident. In some samples ferri-ilmenite occurs in addition to spinel phases. The results of our investigations of the magnetic fraction combined together with the results of our investigations of the stability of the NRM and of the scatter of its directions lead to the conclusion that at several exposures the primary NRM has been preserved. Since the polarities and pole positions obtained from the various exposures differ, the volcanics studied are not synchronous. The palaeomagnetic data are related K-Ar ages carried out on the same material. All of these results have served to formulate an hypothesis concerning the evolution of volcanic activity in the region of the Lower Silesian faults.

G28

SPELEOMAGNETISM - THE PALEOMAGNETIC RECORD CARRIED BY CAVE SEDIMENTS

J.S. Kopper, Anthropology Department, Long Island University

This paper will describe the paleomagnetic records obtained from a number of cave sites as they relate to the conditions of deposit. Both archaeological and non-archaeological cave sediments are represented and it is found that this new sampling context has distinct advantages and unique disadvantages as compared with conventional sampling situations. Among the advantages of certain deposits are minimal post depositional disturbance, constant ambient temperatures and humidity, apparantly simple diagenetic sediment changes, observable sediment geometry and often archaeological time indicators. Variable sedimentation rates and hiatuses in deposition are two recognized problems and are compounded by the general absence of materials for absolute dating.

G29

PROBLEMS OF POLARITY IN THE BRITISH TERTIARY IGNEOUS PROVINCE

A.E. Mussett, Sub-department of Geophysics, University of Liverpool

Attempts to make stratigraphic correlations using magnetic polarity run into a number of problems: i) why are there no normally magnetised lavas corresponding to the normal dykes? ii) why is there no correlation between dyke polarity and geochemical or other groupings, and iii) why is there a predominance of reverse magnetisation even though activity spanned several periods?

These questions and possible solutions are discussed.

G30

PALAEOMAGNETIC STUDIES OF VARVED CLAYS FROM POLAND

Elzbieta Niedziolka, Institute of Geophysics, Polish Academy of Sciences, Warsaw

The magnetic properties of varved clays deposited at Mochty and Plecewice in the Warsaw Basin during the Middle Polish Glaciation about 150,000 years ago are described. Thermomagnetic and mineralogical studies identify magnetite as the carrier of remanence.

G31

PRELIMINARY RESULTS OF A PALAEOMAGNETIC INVESTIGATION OF LAKE SEDIMENTS FROM POLAND

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T.E. Hogg, Department of Geophysics, University of Edinburgh

Fifty-nine six-metre cores were collected from ten lakes in northern Poland during the summer of 1976 using a Mackereth-type pneumatic corer. The NRM of cores from some of the lakes is stable and well defined patterns of inclination and declination changes are obtained. There is generally good agreement between cores from the same lake, correlations being confirmed by matching variations in the NRM intensity and low-field susceptibility. The stability and origin of the remanence will also be discussed.

G32

SOME USES OF INDUCED MAGNETIC MEASUREMENTS IN LAKE SEDIMENTS

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R. Thompson, Department of Geophysics, University of Edinburgh

Magnetic susceptibility, IRM and related measurements provide rapid means of core and sample correlation and can be used to improve the basis on which allochthonous input to lakes can be both quantified and characterized with regard to type and source. The speed of the techniques now available and the environmentally diagnostic nature of some of the induced magnetic parameters measured make magnetic studies a useful complement to stratigraphic, palaeobotanical and chemical analyses. Magnetic properties can also be used as a basis for studying substrate-soil-sediment linkages and transformations within lakes and their drainage basins. Results have been obtained from a wide range of temperate and tropical lakes.

G33

POST-DEPOSITIONAL REMANENT MAGNETIZATION IN SEDIMENTS FROM THE GREEK LAKES

S. Papamarinopoulos, Department of Geophysics, University of Edinburgh

The effect of time and applied field strength on post-depositional magnetization processes have been investigated using sediments from the Greek Lakes. The stability characteristics of the PDRM acquired are similar to those of the NRM. An attempt to recover the palaeointensity record along a complete core is described and the results compared with those obtained using the ARM method.

G34

PALAEOMAGNETIC STUDIES OF THE PRECAMBRIAN: BRITAIN, SOUTH GREENLAND AND SCANDINAVIA

J.D.A.Piper and J.E.F.Stearn Sub-department of Geophysics, University of Liverpool

Comprehensive sampling of these regions is continuing with the aims of defining Precambrian apparent polar wander movements, continental distributions, and geomagnetic field behaviour in as much detail as possible. Results are outlined from the Gardar Igneous Province of Greenland covering lava successions (>1310 m.y.), dyke swarms (1245 m.y.) related to the Mackenzie episode within the Laurentian Shield, and 1175-1160 m.y. dyke swarms, giant dykes and plutons. In Britain results cover thermal demagnetisation studies of stratigraphic sections through the *Torridonian* Sandstones, dyke swarms within the Lewissian foreland, N.W. Scotland, and northern outcrops of the Late Precambrian Unriconian rocks of the Welsh Borderlands. Results from gabbro-anorthosite complexes and slowly-cooled basement terrains within the Baltic Shield are also noted.

G35

GEOMAGNETIC FIELD FLUCTUATIONS RECORDED IN SEDIMENT FROM LAKE TRIKHONIS, GREECE

P.W. Readman, Department of Geophysics, University of Edinburgh

Palaeomagnetic measurements on six-metre cores spanning the time period 1000-6000 B.P. from Lake Trikhonis in Greece will be presented. There is very good agreement between cores from different places in the lake. The NRM intensity is between 10 and 100 μG with median destructive fields of ~300 Oe. A well defined peak in the NRM intensity and the low-field susceptibility indicates the position of an ash horizon which is probably from the Santorini eruption ~3500 B.P. Although an oscillatory pattern of inclination changes exist, the present dating controls preclude concluding whether or not they are periodic.

G36

LOW TEMPERATURE DEMAGNETIZATION INVESTIGATIONS INTO THE CARRIERS OF STABLE NATURAL REMANENT MAGNETIZATION IN SOME FINNISH LAKE SEDIMENTS

J.C. Stober and R. Thompson, Department of Geophysics, University of Edinburgh

Finnish, Holocene sediments from deep lakes carry a stable remanent magnetization. Geochemical, thermomagnetic and coercivity studies have been carried out in order to delimit the origin of magnetization. The NRM, ARM, IRM and initial susceptibility of samples from selected Finnish lake sediment cores are compared. The carriers of reman-

ence, in organic rich sediment, cannot be determined by thermal demagnetization because of chemical change nor by alternating field demagnetization because of the low variation in coercivity spectra. However, cooling of the remanences in zero magnetic field has yielded information about the carriers. The origin of the magnetization is discussed.

G37

A STATISTICAL APPROACH TO CURVE FITTING AND CORRELATION OF SERIAL DATA DISTRIBUTED ON A SPHERE

R. Thompson, Department of Geophysics, University of Edinburgh
R.M. Clark, Department of Mathematics, Monash University

The theory of cross-validation smoothing developed by Clark has been applied to serial palaeomagnetic directions. The method objectively produces a best fitting curve and confidence limits. Palaeomagnetic data, from Lake Windermere (11000 - 0 BP), have been used as a master curve for dating other sedimentary sequences. Analyses of this data are shown. Statistically significant oscillations are found and interpreted in terms of variations in the geomagnetic field. These oscillations are objectively distinguished from minor fluctuations which cannot be justified by the data and cannot be assumed to have been produced by changes in direction of the ancient field.

G38

ARCHAEOMAGNETIC INTENSITY MEASUREMENTS USING A SQUID MAGNETOMETER

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M. J. Aitken Research Laboratory for Archaeology, Oxford University

The high sensitivity of a SQUID magnetometer permits the use of such a small sample that the heating time in the Thellier technique can be shortened to less than a minute. This makes it practical to heat the sample in situ within the magnetometer and in turn this makes it possible to modify the Thellier technique in a way that shortens the measurement time too. Results are reported for ancient pottery and other forms of fired clay as well as a sample from an historic lava flow.

Rock Magnetism

G39

AN EXPERIMENTAL STUDY OF Ti DIFFUSION IN MAGNETITE

R. Freer, Z. Hauptman, Department of Geophysics and Planetary Physics, University of Newcastle upon Tyne

Diffusion coefficients of Ti^{4+} in single crystal magnetite have been determined over the temperature range 600 - 1300°C at constant p_{O2}. Interdiffusion experiments were performed on couples of Fe_3O_4 (single crystal) - $Fe_{2.8}Ti_{0.2}O_4$ (powder) under defined atmospheres. Profiles of Ti and Fe were obtained by electron probe microanalyses, and D calculated by the Boltzmann-Matano method. Diffusion coefficients and activation energy for the process are reported and compared with previous indirect estimates. Data obtained are useful for estimating rates of oxidation, and transformation of titanomagnetites to other phases. Combined with data for Fe diffusion a better understanding of kinetics of the system will be gained.

G40

A METHOD FOR PREPARATION OF IRON-TITANIUM SINGLE CRYSTALS

Z.Hauptman Department of Geophysics and Planetary Physics, University of Newcastle upon Tyne.

A novel method for preparation of single crystals from the melt has been developed to provide materials for research into thermoremanent properties of titanomagnetites. In order to approach more closely the composition of natural titanomagnetites it is necessary to synthesize not only pure titanomagnetites but also their substituted equivalents, i.e., containing minor elements (Mg, Al, Cr, etc.). An almost complete lack of equilibrium data for those more complex systems is a serious difficulty for conventional growing methods from melts. The growing apparatus described makes it possible to assess the solid-melt-f_{O2} equilibria in situ prior to growing, and thus enables a good rate of success in producing single phase crystals. Compositional zoning in the "as-grown" crystals inherent to the technique must be removed by an aftertreatment.

G41

OXYGEN FUGACITY VALUES AND CURIE TEMPERATURES FOR THE MIDDLE MEMBERS OF THE CUBIC TITANOMAGNETITE s.s. SERIES

Z.Hauptman, A.L.Campbell Department of Geophysics and Planetary Physics, University of Newcastle upon Tyne.

Previously, an unusually steep slope of T_c as a function of f_{O2} had been observed in the titanomagnetite $Fe_{1.4}Ti_{0.6}O_{4-\gamma}$ (TM 60) which was gradually oxidized at high temperature (1573 K) over its single phase stability field and quenched. The study has now been extended over the range TM40 - TM60. The steepness of the T_c-f_{O2} plot increases even more towards the iron richer member. Within the same compositional region, i.e., TM40-TM60 the s.s. series shows a marked departure from Vegards rule: when T_c for stoichiometric titanomagnetites are plotted against compositional parameter x an almost straight line results for $0 < x < 0.4$ and $0.6 < x < 1.0$ with slope $\Delta T_c/\Delta x \simeq 700$ K. The two straight parts appear to be offset by 35-40 K over the $0.4 < x < 0.6$ range. Hystereses of similar magnitude for T_c determined from susceptibility - temperature plots have been occasionally observed. At present, investigation are being carried out in a search for possible order-disorder transitions or similar phase transformation phenomena.

G42

LABORATORY SIMULATION OF MAGHEMITIZATION AND DEUTERIC OXIDATION OF TITANOMAGNETITE-INFLUENCE ON COERCIVE FORCE AND OTHER MAGNETIC PROPERTIES

J.B. O'Donovan, Department of Geophysics and Planetary Physics, University of Newcastle upon Tyne

(i) Maghemitization: Twenty samples were prepared by oxidizing finely ground (~0.1 μm) titanomagnetite, containing up to 0.35 Mg^{2+} ions per formula unit, in air at temperatures below about 350°C. Hysteresis loops indicate the monodomain state with coercivity ranging from 1.5 x 10^5 A/M in near stoichiometric material to 10^4 A/M in the most highly oxidized. Rotational hysteresis parameters similarly fall with progressive magnetization.
(ii) Deuteric oxidation: Samples were prepared by oxidation of coarse ground (~10 μm) titanomagnetite in air at temperatures up to 700°C. The scale of the resultant intergrowths was at or below the optical limit but could be resolved by the electron microscope. The hysteresis loops of the most highly oxidized samples are typical of dispersed monodomain magnetite rods.

G43

ROTATIONAL HYSTERESIS IN HAEMATITE

W.H. Owens Department of Geological Sciences, University of Birmingham

Adopting a model for fine-grained haematite, in which the magnetization is restricted to the basal plane, within which there is a single easy direction, torque curves have been calculated for a range of basal plane inclinations, easy directions and field strengths. These show that the model provides a simple explanation for the well-known persistence of rotational hysteresis to very high fields. It also predicts that anisotropy of rotational hysteresis should occur for distributions of haematite grains showing preferred orientation. This has been verified by torque-meter measurements on Cambrian slates from North Wales.

G44

MAGNETIC ANISOTROPY OF DEFORMED CALCITE AGGREGATES

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E.H. Rutter Department of Geology, Imperial College, University of London

High-field torque-meter measurements of diamagnetic susceptibility anisotropy of a suite of samples of Carrara marble, axially shortened at 1.5-3.0 10^8 Pa confining pressure and 20-500°C (usually 400°C) by amounts up to 50%, have been compared with optical measurements of c-axis preferred orientation. Given the anisotropy of calcite, quantitative comparison is possible. Calcite anisotropy has been measured on undeformed and deformed single crystals. It is found that optical and magnetic measurements agree only if allowance is made for deformation as well as reorientation of the calcite grains.

G45

A MAGNETIC STUDY OF SYNTHETIC TITANOMAGNETITE SUBSTITUTED BY ALUMINIUM

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Sintered polycrystalline specimens in the systems $Fe_{2.4-\delta}Al_\delta Ti_{0.6}O_4$ and $Fe_{2.6-\delta}Al_\delta Ti_{0.4}O_4$ ($0 \leq \delta \leq 0.2$) were prepared by a method of partial self-buffering with two firings at 1300°C. X-ray powder pictures and Curie point determinations confirmed that the prepared samples are single phase spinels. Both Curie temperature and unit cell edge decrease with increasing Al concentration. The materials were ball-milled to produce samples in the mono-domain or pseudo-single domain size range to be used for testing models for the acquisition of thermoremanent magnetization.

G46

MAGNETIC PROPERTIES OF ULVOSPINEL

P.W. Readman, Department of Geophysics, University of Edinburgh

Low temperature magnetisation curves for synthetic polycrystalline ulvöspinel will be presented. The spontaneous moment below 60 K is < 0.2 emu/g and at 4 K the magnetisation curve up to the maximum field of 24 kOe is linear. Between 60-120 K a weak ferromagnetic moment is present with a maximum value of 1.8 emu/g at 100 K. When the sample is cooled in the presence of a high magnetic field, the thermomagnetic curve has the appearance of a Néel N-type with a 'compensation temperature' of about 40 K.

G47

MAGNETIC PROPERTIES OF TITANOMAGNETITE SINGLE CRYSTALS

P. Tucker Department of Geophysics and Planetary Physics, University of Newcastle upon Tyne.

A suite of single crystal specimens of approximate composition $Fe_{2.4}Ti_{0.6}O_4$ were prepared from the melt by the "micro-Bridgman" technique. The zoned "as-grown" crystals were analysed using the electron microprobe and suitable atmospheres chosen for after-treatment at 1300°C. After such treatment the crystals were homogeneous and showed well defined Curie points. The crystals were formed into spheres 1-1.5mm in diameter and orientated for magnetic measurements. These include the temperature dependence of coercive force, determined using a vibrating sample magnetometer, equipped with a vacuum furnace, and curves of acquisition of thermoremanence against applied field.

G48

MAGNETIC INTERACTION BETWEEN IRON AND ULVÖSPINEL

R. Veitch and A. Stephenson. Institute of Lunar and Planetary Sciences, School of Physics, University of Newcastle upon Tyne.

Samples of ulvöspinel containing large iron inclusions of various shapes have been prepared. They were then magnetized at different temperatures and in different directions. Marked differences in the behaviour of the remanent magnetizations of the composite samples were observed as they were cycled through the ulvöspinel Curie point. This is interpreted as being due to magnetostatic interaction between the two phases.

G49

A ROTATING-HEAD TORQUE MAGNETOMETER CONTROLLED BY A MICROPROCESSOR

D. Wilson School of Physics, University, Newcastle upon Tyne.

The present instrument, which incorporates a taut dual fibre suspension and photocell bridge detector handles torques up to 3×10^{-4} N-m with a noise level of $\sim 10^{-8}$ N-m. A novel feature is that the torque head rotates and the electromagnet remains stationary. The microprocessor is used to control the sampling interval and rotation rate, to store the data in digital form and can also be used for in-situ data analysis eg. calculation of areas under curves (rotational hysteresis loss). The data is available as a visual display or print out/punched paper tape. For more elaborate calculations the data tapes may be read into a large computer.

LITHOSPHERIC STUDIES

Explosion Seismology

L1

THE HEBRIDEAN MARGIN SEISMIC PROJECT OF 1975

A.R. Armour and M.H.P. Bott
Department of Geological Sciences, University of Durham

The Hebridean Margin Seismic Project focussed on an east-west line along 58°N from Rockall Trough to the east coast of the mainland. Time term analysis yields P_n of 8.09 km/s and average P_g of 6.1 km/s. P_g time terms vary up to 0.4 seconds and correlate closely with gravity and magnetic anomalies. P_n time terms average 2.7 seconds on the shelf and Outer Hebrides, 3.1 seconds over the Minch, and they increase eastwards across Scotland from 2.5 to 3.0 seconds. The average time term for Rockall Trough at 58°N is 2.97 seconds representing a crustal thickness of about 8 km beneath 3 km of sediments.

S WAVES IN THE LISPB CRUSTAL PROFILES

M. Assumpcao and D. Bamford - Department of Geophysics, University of Edinburgh

Many shots in the LISPB profiles produced shear waves with large amplitudes which were recorded by 3-component stations. A preliminary crustal model for S velocities is presented for the segments ALPHA and BETA (Loch Eriboll to Carlisle). The phases best observed were usually S_g and S_MS, but P to S conversion at the Moho was also recorded. Travel times of these phases give Poisson Ratio in the range 0.240 to 0.255 for the middle and upper crust, whereas sedimentary basins seem to require values greater than 0.26 and possibly as high as 0.30. Multiplication of horizontal and vertical components was used and its usefulness in determining S wave onsets is reassessed.

L3

LONG-RANGE LISPB OBSERVATIONS

The LISPB Working Group (presented by D. Bamford, Department of Geophysics, University of Edinburgh)

The special effort made during the LISPB experiment to secure good quality long-range data resulted in excellent observations to distances of 1000 kms. These clearly show that the P_n phase refracted from the uppermost mantle dies out beyond 250 to 300 kms distance, and is replaced by a sequence of later, faster phases of varying horizontal persistence returned from the lower lithosphere. After careful correction by ray-tracing for variations introduced by lateral crustal inhomogeneities, these phases can be interpreted in terms of velocity contrasts in the depth range 50-100 kms using theoretical travel-time and synthetic seismogram modelling. These results seem to confirm earlier results obtained in France which suggested that the lower lithosphere has a hitherto unexpected fine structure.

L4

LONG SEISMIC LINES IN THE BRISTOL CHANNEL AREA

M. Brooks, M. Bayerly and D.J. Llewellyn
Department of Geology, University College of Swansea

A report is given of long seismic lines established in the Bristol Channel area during the past three years. Quarry blast recordings in South Wales provide a network of profiles up to 45km long giving information on the local depth to Precambrian basement. Large charges of Aquaflex explosive cord detonated in the Bristol Channel have been recorded along several lines from Pembrokeshire to the Mendips and in North Devon. A maximum range of nearly 100km has been achieved. Provisional geological interpretation of selected lines will be presented, and the case for a major thrust under Exmoor will be re-examined in the light of the new data and of a re-interpretation of the gravity gradient across Exmoor.

L5

LEWISIAN UNITS SEISMIC TRAVERSE

J. Hall Department of Geology, University of Glasgow

A 40 km refraction line was shot from Badcall Bay to Durness in NW Scotland across the Laxford Front separating variably-retrogressed Scourian granulites (of average composition equivalent to intermediate igneous rocks) from reworked acid quartzo-feldspathic gneisses, in order to discover whether the granulites continue at shallow depth below the acid gneisses as predicted by gravity and magnetic models. Each of 89 vertical seismometer stations was used to record arrivals from four shot points. Time-distance plots of first arrivals show a scatter of 0.01s about smooth curves to be interpreted by ray-tracing methods. The velocity structure is compared with results of other in-situ measurements of velocity and lab. measurements on hand-specimens at variable pressure. So far, there is no clear evidence of laterally-extensive granulites under the gneisses at depths less than 4 km, though some high-velocity patches are present.

L6

OBSERVATIONS OF PS REFLECTIONS FROM THE MOHO

A.W.B.Jacob and D.C.Booth , I.G.S., Global Seismology Unit, Edinburgh.

In a study on the absence of PS reflections in crustal record sections Fuchs(1975) has recommended that a search for PS reflections on record sections be carried out,since the results should give more information on the nature of the Moho than is available from P wave data only. Observations of a PS phase on a section in NW Scotland are presented here, with recommendations as to how the phase may be more clearly detected and observed by signal processing.

Reference: Fuchs,K. J.Geophys.,41,445-462,(1975).

L7

ON THE INVERSION OF LONG RANGE SEISMIC PROFILES

E.L.N. Kennett Department of applied Mathematics and Theoretical Physics, University of Cambridge

The use of controlled sources has markedly improved our knowledge of the seismic structure of the lithosphere. In particular the recent use of relatively closely spaced recording stations has shown the existence of fine structure in the character of the seismic wave field. Both travel time inversion and waveform analysis may be used to construct velocity distributions but the final structure obtained will be dependent on the attention structure. Improved knowledge of lithospheris structure in complex areas depends on making allowances for lateral variation in crustal structure along a profile. Topography at the crust mantle interface can have a significant effect on the recorded wavefield.

L8

TOWARDS A MORE DETAILED SEISMIC PICTURE OF THE OCEANIC CRUST

B.L.N. Kennett Department of Applied Mathematics and Theoretical Physics, University of Cambridge

For many years a very simple picture of the oceanic crust divided into four uniform seismic layers has prevailed. Recently however the use of greater shot densities and more sophisticated interpretation techniques is beginning to change the model of the crust. Systematic travel time inversion and detailed analysis of recorded wave forms using synthetic seismograms place additional constraints on the velocity distribution within the oceanic crust.

L9

THIN CRUST IN THE PHILIPPINE SEA

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Much of the Philippine Sea is significantly deeper than would be predicted by its ages and the depth vs. age curve for the Pacific. This may imply that its crust is significantly thinner than that of normal ocean basins. In July 1976 on the joint expedition "Indopac" between Scripps Inst. of Ocean. and the National Taiwan Univ. we shot 7 reversed or split two-ship refraction lines in the Parece Vela and West Philippine basins to test this possibility.

These new results suggest that the total crustal thickness may be 2 to 3 km thinner than Pacitic crust of a similar age. This is primarily due to an "oceanic" layer (v=6.7 km/sec) only 3.1 km thick as opposed to 5.3 km for normal oceans of tnis age. These crustal differences when isostatically compensated can produce a large fraction, but not the entirety, of the depth anomalies in these basins.

L10

DISPLAY AND PROCESSING OF SEISMIC WIDE ANGLE REFLECTION DATA FROM DISPOSABLE SONOBUOYS

P.R. Miles, Institute of Oceanographic Sciences, Wormley, Godalming, Surrey

A new method for displaying disposable sonobuoy data on a variable area recorder has been developed after identifying the need to improve data display comparable with recording and interpretation techniques. Each signal trace is digitised, processed and delayed using a mini-computer capable of shipboard operation. The final display flattens the reflection hyperbolae and enables improved trace correlation and reflector digitisation. The method has particular application to interpretation of poor quality records.

L11

THE CRUSTAL STRUCTURE BENEATH NORTHERN BRITAIN

The LISPB Working Group (presented by K. Nunn, Department of Geological Sciences, University of Birmingham)

Interpretation of data from the 1974 LISPB experiment (Bamford et al., 1976, GJRAS, 44, 145) has resulted in a detailed seismic cross-section of the crust and uppermost mantle beneath Northern Britain. The main features in this section are
(i) a possible horizontal discontinuity in the Pre-Caledonian basement, between the Southern Uplands Fault and the Stublick Line,
(ii) a lower crustal layer, velocity in excess of 6.7-6.8 km/s, which appears to shallow beneath the Southern Uplands/ Midland Valley, and
(iii) a change in the nature of the Mohorovicic discontinuity, from a sharp transition (< 2 kms) in the north to a gradational change (> 5 kms) in the south.

L12

P WAVE STRUCTURE OF THE LITHOSPHERES (0 - 10 M.Y.) NORTH OF THE AZORES

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Four seismic refraction lines up to 400 km long indicate the upper lithosphere structure of the Mid-Atlantic Ridge close to the Azores. Although energy propagates across the ridge axis within the crust the axial region prevents propagation within the mantle. A profile along the 4 m.y. isochron shows, below a 7.6 km s^{-1} layer, a low velocity zone underlain by an 8.3 km s^{-1} refractor at 9 km depth. Higher velocities found on east-west lines shot towards the ridge can be attributed to this refractor if it dips away from the ridge. A 9 m.y. isochron profile detected an 8.3 km s^{-1} refractor at 30 km depth. We explain our data by using a velocity model based on a petrological model which incorporates significant hydration reactions.

L13

SEISMIC REFRACTION STUDIES OF THE UPPER CRUST IN THE EAST MIDLANDS

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The paper is a report on a part of the Leicester University Charnwood Block Project, the aims of which are to investigate the nature of Charnwood with respect to the surrounding geology, and to study the deep structure by means of earthquake data collected from an eight-station seismic array which was operational on Charnwood for five months. Two reversed seismic lines using quarry blasts as sources, were set up during the summer of 1976. The first of these was undertaken in collaboration with the IGS and was between Mancetter quarry near Nuneaton and Bardon Hill quarry to the NE in Charnwood. Twenty-two vertical seismometer stations were set out along the twenty-four kilometer line. Mancetter quarry fired an 1800 lb. shot split

between seven 17 ms. relays. Bardon quarry fired a 2900 lb. unrelayed shot. Quarry blasts from The Croft and Whitwick quarries were also recorded by 15 and 6 Geostore stations respectively. The second line was NNW from Bardon to Ballidon quarry near Ashborne in Derbyshire. This was to investigate the basement ridge extending southwards from the Derbysnire Dome to Charnwood as suggested by the gravity data. The paper discusses the results obtained from the Mancetter-Bardon seismic line. A time term analysis was applied to this data, together with quarry blast data recorded by the Charnwood array. A preliminary interpretation shows a basement of velocity 5.6 km/s. The line crosses a 7 km. wide horst bounded by faults with throws of .5 km. at a depth of approximately 1.5 km. The centre of this structure is 9 kms. from Bardon Hill quarry. The position of this upfaulted block coincides with the southern extension of the gravity high that exists to the south of the Derbyshire Dome.

L14

DETAILED STUDIES OF THE UPPER OCEANIC CRUST USING A LARGE AIR GUN AND BOTTOM RECEIVERS

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Over the last 5 years a number of seismic refraction profiles have been recorded by IOS pop-up bottom seismic recorders (PUBS) using a 16 l airgun as a sound source. The gun was fired every 1 or 2 minutes while being towed at 4 to 5 knots. Refracted arrivals are often detectable to ranges of over 20 kms. Some examples of these airgun profiles will be presented and the upper crustal structures deduced from them will be discussed.

L15

KRISP 1975. SEISMIC PROFILES WITHIN THE GREGORY RIFT VALLEY, KENYA

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In the summer of 1975, two reversed refraction lines were shot within the Rift Valley in Central Kenya. One line was N-S in the middle of the Rift, about 30 kms. long between Lakes Hannington and Baringo. The other was E-W across the Rift, of length 50 kms, between Lake Baringo and the Kerio Valley. Recording positions were at 800 m. intervals along these lines with shot points at Lakes Hannington and Baringo (2 shot points in each) for the N-S line and at Lake Baringo and the River Kerio with two intermediate points for the E-W line. Interpretation of the seismic data for both lines indicates an essentially two layered structure. On the N-S line, an upper layer (lavas with sediments) of velocity 2.4 km/s rests on basement of velocity 5.75 km/s. The interface is fairly flat at about 1.5 km. depth but deepens to 3.5 km. towards Lake Baringo. The E-W line crosses the main structural trends and is understandably more complicated. At the eastern end of this line the surface layer (mainly Baringo sediment) velocity is about 2.30 km/s and this increases to 3.63 km/s at the western end where lavas are dominant. The basement velocity along this line is lower than that along the N-S line at 5.45 km/s. Gravity was also measured at each seismic recording site and together with the gravity data already available and the control provided by the seismic work, an interpretation of a detailed nature became possible. When the gravitational field computed for the E-W seismic model is compared with the observed Bouguer Anomalies, a large positive residual is seen centred on 36°E. This has been interpreted in terms of a basic intrusion whose top surface varies from 6 to 9 km in depth. This compares with similar intrusions penetrating to within 3 km. of the surface which have been postulated further to the north and south from gravity data alone. Thus the axial intrusion appears to be continuous through this area although the gravity data alone does not show this.

General Geophysics

L16

THE ACQUISITION AND INTERPRETATION OF A GAMMA-RAY SURVEY OVER THE LOCH DOON GRANITE.

J.Cassidy, G.C.Brown and J.Hennessy. Sub-Department of Geophysics, University of Liverpool.

Field gamma-ray measurements over the Loch Doon granite pluton, Southern Scotland, show a qualitative similarity with available petrochemistry and emphasise the gradational change from the tonalite margins to two distinct granite cores within the intrusion. A technique for

calibrating the field spectrometer in terms of K, U and Th concentrations has been devised using neutron activation analysis of selected samples. The present results considerably amplify radioactive element distribution maps previously determined using only neutron activation data. The origin of the granite by partial melting in the lower crust or upper mantle with subsequent fractionation and/or roof assimilation will be discussed in the light of available geophysical and petrochemical data.

L17

GEOPHYSICAL EVIDENCE ON THE STRUCTURE OF THE FAEROE-SHETLAND ESCARPMENT

J A Chalmers, A Dobinson, A Mould and D K Smythe, Marine Geophysics Unit, Institute of Geological Sciences.

New geophysical evidence, refraction and reflection seismics gravity and magnetics, suggest that the Faeroe-Shetland Escarpment is formed by a wedge of Palaeocene lavas overlying a considerable thickness of Mesozoic sediments. The implications of these results for the plate-tectonic history of area are discussed.

L18

GEOPHYSICAL INVESTIGATION OF THE PRE-CARBONIFEROUS BASEMENT OF THE ASKRIGG BLOCK YORKSHIRE

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The gently-dipping lower Carboniferous limestones of the Askrigg Block almost completely conceal the basement rocks which give rise to strong magnetic and Bouguer gravity anomalies. Detailed gravity and magnetic surveys and interpretations of the results carried out to help in the siting of two deep boreholes have revealed more details of the distribution of the basement rock types. The most likely cause of the pronounced Bouguer anomaly low in the centre of the block was thought to be a large granite intrusion whose existence was subsequently proved by the Raydale Borehole in 1973. A gravity survey of the area over the granite revealed a central cupola with deeper cupolas on two sides joined at depth and giving the intrusion an overall east to west elongation. Strong magnetic anomalies abutting the Bouguer anomaly low suggest that the granite has beer intruded in places through a magnetic horizon in the basement. This was intersected by a borehole in 1976. Geophysical models for the granite and the host rocks are presented and their geological significance discussed.

L19

AN INTERPRETATION OF GRAVITY AND MAGNETIC DATA IN THE ENGLISH CHANNEL AROUND THE ISLE OF WIGHT

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A gravity map of the Isle of Wight area is interpreted in terms of structure underlying the known surface geology. Magnetic results are used to indicate the regional significance of this structural analysis.

L20

CRUSTAL DEVELOPMENT OF THE CENTRAL WEST GREENLAND EMBAYMENT.

J.W. Elder. Department of Geology, University of Manchester.

A quasi-hydrostatic model of the development of an intra-continent rift zone is described, based on geological and geophysical measurements of the Cretaceous-Lower Tertiary sedimentary and volcanic embayment of central West Greenland. A gravity contrast reaching 170 milligal across the embayment is interpreted as a crustal thinning up to 80%. The model is calibrated against: seismically determined terrestrial sediment thickness; thickness of early pillow breccias; height of the lava pile; and ultimate water depth. Superb field data allow a detailed investigation of models of this type.

L21

RECENT GEOPHYSICAL STUDIES OF THE GULF OF ADEN

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In 1975, a new geophysical survey was

made aboard the RRS SHACKLETON with the specific objectives of discovering more about the sea floor spreading history of the Gulf and the evolution of young continental margins. In the westernmost part, 16 continuous profiles of bathymetry, total magnetic intensity and gravity were made along N.32°, i.e. the direction of separation of Arabia and Somalia. The profiles extend as far to the shores as practicable, i.e. to 3 n. mls off Somalia to 12 n.mls off Arabia. Analyses of the profiles reveal that the present active centre has been spreading for only a few million years and that there was a previous earlier phase of spreading in the Oligocene. The magnetic lineations are found to extend almost as far as the shorelines and the significance of this for the evolution of continental margins is discussed.

L22

CALEDONIAN GRANITES: A RARE THERMAL EVENT

J.Hennessy and G.C.Brown Sub-Department of Geophysics, University of Liverpool.

Knowledge of the thermal regime of continental crust, and of geochemical and isotope data leads to a conceptual model for the site of genesis of the large granitic batholiths of the world. From a consideration of both steady state and dynamic heat flow and water diffusion models, and knowing the bulk properties of the end result, we can attempt to specify the physical properties of this source region, and to outline the form of a numerical solution for the problem of granite genesis.

L23

A GRAVITY SURVEY OF THE SOUTH MIDLOTHIAN COALFIELD AND SOUTHERN UPLANDS FAULT SYSTEM

R.G. Hipkin, Department of Geophysics, University of Edinburgh

Approximately 1000 gravity observations have been made near the S.U.F.S. east of the Lanarkshire border. A 400 element, three-dimensional inversion of this data will be presented as a model for part of the S.U.F.S. and the Midlothian Coalfield.

The north-westerly downthrow of the S.U.F. (s.s.) has a gravitational expression of typically 70 gu. Displacement was very largely pre-Namurian and active during Upper Old Red Sandstone times. It is terminated under the Midlothian Coalfield Roslin-Vogrie Fault System. This appears to have either pre-dated it or moved contemporaneously, although movement continued throughout Carboniferous times.

Neither the conventional offset of the S.U.F.S. along the Cockmuir Fault to join the Lammermuir Fault, nor the Lammermuir Fault itself are defined gravitationally above the 5 gu level.

A provisional interpretation of the regional field is made in terms of the deep structure of the Southern Uplands.

L24

SECULAR VARIATION OF GRAVITY IN SCOTLAND

R.G. Hipkin, Department of Geophysics, University of Edinburgh

Tests with the LaCoste-Romberg gravity meter G-275 show that random reading errors generate a standard deviation of about 0.02 gu (2 μgal) under normal microseismic conditions, although reproducible systematic errors are commonly an order of magnitude larger, due mainly to thermal and residual tidal disturbances. Non-equilibrium temperature response gives characteristic instrumental drift of typically 0.3 gu over a 2 hour period, but can be eliminated by calibration. Non-elastic earth tides vary rapidly near the coast and are the principal difficulty with British secular gravity experiments. Preliminary analysis suggests that this may be overcome statistically. If a 0.02 gu uncertainty can be achieved in Britain, then estimates of post-glacial uplift in Scotland should generate significant relative gravity changes in a 2 to 10 year period, on a simple isostatic hypothesis. Preliminary results by Petersson and Kiviniemi from Fennoscandia may imply regional variation of lithospheric response, with excess rates of change to the west, so that British variations could be more rapid. Seven gravity stations associated with O.S. Fundamental Bench Marks east to west between Dunbar and Bowling (Glasgow), and north to Crubenmore (Newtonmore) are being measured as the basis of a secular gravity study.

L25

GEOMAGNETIC INDUCTION STUDIES IN KENYA

V.R.S. Hutton, D. Rooney, I.M. Brazier and E. Mbipom, Department of Geophysics, University of Edinburgh

Magnetotelluric and magnetovariational measurements in the period range 10-1000 seconds have been made at 12 locations in and around the Kenya Rift Valley. The data have been processed in a number of ways, including the evaluation of (a) maximum and minimum response functions and (b) apparent resistivity versus period curves and the plotting of hypothetical event contours. For each procedure, the results are qualitatively consistent with the existence of a good conductor below the Rift Valley extending into the upper mantle from shallow crustal depths. The results of this study are discussed in association with those of other induction studies in the Great Rift Valley of Africa and of other geophysical investigations in Kenya.

L26

A GEOMAGNETIC INDUCTION STUDY AT MICROPULSATION PERIODS IN THE SOUTHERN UPLANDS OF SCOTLAND

A.G. Jones and V.R.S. Hutton, Department of Geophysics, University of Edinburgh

The existence of a major electrical conductivity anomaly in the region of Eskdalemuir has previously been indicated by geomagnetic deep sounding studies using periods greater than 12 minutes (Edwards et al., 1971). This has now been followed by magnetotelluric measurements at 13 locations along lines perpendicular and parallel to the strike of the proposed anomaly using periods extending down to 10 seconds. The use of the magnetotelluric as well as geomagnetic deep sounding techniques and the analysis of shorter period phenomena has aided the delineation of the crustal conductivity structure in this region. One- and two-dimensional interpretations of the results are presented and their tectonic implications are discussed.

L27

GEOPHYSICAL MODELLING AND PETROGENESIS OF THE SHAP GRANITE

C.A. Locke and G.C. Brown, Sub-department of Geophysics, University of Liverpool

Gravity and magnetic data collected from the area of the Shap granite instrusion have been used to produce a 3-dimensional model of the pluton. The model of the detailed subsurface structure formed using the gravity data broadly resembling an inverted cone was used in conjunction with palaeomagnetic and susceptibility measurements in an attempt to locate the source of a strong local induced magnetic anomaly. It appears that the granite is either vertically inhomogenous, with decreasing acidity and hence increasing susceptibility with depth or that stable magnetic minerals are present at the expense of silicate phases beneath outcrop level. The relative importance of these suggestions will be discussed in the context of the petrogenesis of this intrusion.

L28

RESULTS OF GRAVITY AND MAGNETIC SURVEYS IN THE FORTIES AREA OF THE NORTH SEA

A K Rochester, Marine Geophysics Unit, Institute of Geological Sciences

The results of marine gravity and magnetic surveys in the Forties area of the northern North Sea are interpreted and discussed in relation to deep geological structure, particularly that which is associated with Jurassic volcanic activity.

L29

THE STRUCTURE AND ORIGIN OF KURCHATOV FRACTURE ZONE, NORTH ATLANTIC OCEAN

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Kurchatov Fracture Zone (40°30'N) has a 20 km dextral offset and appears to be at least 100 km from the nearest neighbouring fracture zones. Long-range side-scan sonar and other geophysical methods suggest it is being produced by oblique spreading within the offset zone, rather than by a transform fault. The fracture zone walls are composed of NE-SW scarps en-echelon, giving them a serrated outline in plan. A model to account for the bathymetric relief of the fracture zone is presented and is tested against observed gravity anomalies.

L30

THE STRUCTURE OF KING'S TROUGH, NORTH-EAST ATLANTIC, FROM SEISMIC AND GRAVITY DATA

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King's Trough is a linear, NW-SE trending feature about 460 km long, situated 500 km northeast of the Azores. It consists of a series of basins, each 50 to 100 km long, about 15 km wide, and trending E-W to NW-SE. These are flanked by two linear ridges. Although the whole structure is roughly symmetric about its axis, in detail the southwest side appears more complex, and rises from shoaler sea-floor. King's Trough appears to be part of an ancient plate boundary which joined the Mid-Atlantic Ridge to the Pyrenean compression zone. However, the precise relative motions at the boundary are unclear, though the total displacements probably did not exceed a few tens of kilometres. We present models of the deep structure of the Trough based on gravity and seismic data, and we combine these with other geophysical data to discuss possible origins of the feature.

L31

A GEOMAGNETIC DEEP SOUNDING STUDY IN NORTHERN SCOTLAND

J.M. Sik and V.R.S. Hutton, Department of Geophysics, University of Edinburgh

Scotland is a tectonically complex area and this is reflected in the magnetic field time variations recorded by two arrays of Gough-Reitzel magnetometers. These arrays were operated in 1973 and the first array consisted of twenty instruments deployed over that area of Scotland lying North of the Highland Boundary Fault. Nine simultaneous events have been digitized for this array. Various aspects have been studied: the magnetograms themselves; maps of Fourier amplitudes and phases of the magnetic field components for each of the events; transfer functions; horizontal field polarizations and hypothetical event analyses. All the treatments reveal, superimposed on effects due to seas and source fields, striking variation anomalies. Some of these effects may be attributed to major structures such as the Great Glen (where further work is in progress), but an interesting attenuation of Z is observed at stations lying on the ophiolitic suites running through the Grampians and is indicated to a lesser extent by the sparser data in the far north. The analyses of the data will be presented with a tentative interpretation where possible.

L32

REGIONAL GRAVITY ANOMALIES OVER THE EAST AFRICAN RIFT SYSTEM

W.T.C. Sowerbutts, Department of Geology, University of Manchester

The nature and extent of regional gravity anomalies over the section of the East African Rift system between Central Africa and midway along the Red Sea are described. The extent of regional negative Bouguer anomalies allows an outer limit to be placed on the area underlain by low density upper mantle. This area includes places where there is little surface evidence of rifting.

L33

A GRAVITY MAP OF KENYA

C.J. Swain and M.A. Khan Department of Geology, University of Leicester

This map is based on over 9000 gravity observations, made principally by the University of Leicester in the last ten years with a La Coste Romberg gravity meter as part of a study of the deep structure of the African Rift. The station interval varies from < 1 km in the rift, to > 10 km elsewhere and has been determined by the availability of roads. Other measurements were made from rail cars along railway lines, from a boat along the shore of Lake Turkana, on foot, and by helicopter. Most of the station elevations were determined barometrically. Terrain corrections were carried out using a newly developed programme in which local corrections are computed by interpolation between 1 km grid points. The Bouguer anomaly map to be presented was obtained using automatic interpolation for estimating the values at regular grid points based on Briggs' method of minimum curvature. The regional gravity field is satisfactorily fitted by a 7th order orthogonal polynomial surface which contains a NW - SE elongated saddle in the North-east and a bowl-shaped

minimum in the South-west coincident with the culmination of the Kenya Dome, suggesting regional isostatic comparison. A spectral study of the gravity and topographic data is in progress. The residual gravity map shows a number of features which clearly correlate with the visible geology. There are lows associated with the light sediments in the Kavirondo trough, and the light volcanics near Mount Kenya. An irregular high in the north-east extends for 500 km and is attributed to high density basement. Further east a step anomaly of 80 mgal occurs indicating a fault with a throw of several km. An intermittent gravity high is present along the rift axis and a number of large and prominent calderas lay on it. Seismic refraction data suggests that the high is obscured in places by light sediments near the surface. The indications are that the rift axis is underlain by a continuous axial intrusion.

L34

VARIATION IN CRUSTAL STRUCTURE ALONG THE LESSER ANTILLES ISLAND ARC.

G.K. Westbrook Department of Geological Sciences, University of Durham.

Gravity, magnetic, seismic refraction and reflection data show that in addition to individual variations between islands, the gross structure of the Lesser Antilles arc changes significantly along its length. The arc can be divided into 3 main segments. The southern part has a single line of islands with a crustal root 30 km deep. The middle contains the volcanic arc and east of it a buried ridge: both have roots. The northern segment has two arcs with outside them a bathymetric shelf which does not have the same structure as the volcanic islands. The deformed sediment complex in front of the arc also shows corresponding structural changes. The possible reasons for these variations are discussed.

Laboratory and Theoretical Studies

L35

LABORATORY MEASUREMENTS OF SEISMIC VELOCITIES IN LEWISIAN METAMORPHIC ROCKS

F.M. Al-Haddad Department of Geology, University of Glasgow

Seismic velocities in suites of hand-specimens from the Precambrian Lewisian metamorphic complex, N.W. Britain, have been measured in the laboratory to reveal the dependence of velocity on mineral constituents and crack closure. Effective velocities and densities of constituent minerals have been found by multiple-regression analysis. The results are compared with those of In-Situ velocity measurements, of the 'Lewisian Units Seismic Traverse', and of other crustal profiles in the area.

L36

ISOSTATIC COMPENSATION ON A CONTINENTAL SCALE : LOCAL VERSUS REGIONAL MECHANISMS

R.J.Banks Department of Environmental Sciences, University of Lancaster

Using linear programming methods, the isostatic response function for the continental U.S.A. is shown to be incompatible with any local compensation model. A simple regional compensation model that treats the lithosphere as a thin elastic plate overlying a liquid is investigated. If only positive density gradients are allowed in the plate, the response of this model fits the data at the 95% confidence level, provided the flexural rigidity of the pl lies in the range 10^{21} to 10^{22} N m. These bounds imply that at most only a thin surface layer of the lithosphere can be treated as elastic.

L37

AMPLIFICATION OF UPPER LITHOSPHERIC STRESSES BY UNDERLYING VISCOELASTIC CREEP WITH APPLICATION TO CONTINENTAL SPLITTING MECHANISM

M.H.P. Bott and N.J. Kusznir, Department of Geological Sciences, University of Durham.

The rheology of the lithosphere can be crudely modelled by an upper elastic layer about 20 km thick above a lower viscoelastic or "Bingham" layer about 60 km thick. Finite element analysis applied to such a model shows that equilibrium deviatoric stresses in the elastic layer produced by boundary stresses

or gravitational body forces are amplified relative to a purely elastic lithosphere, by a factor about equal to the ratio of lithospheric to elastic layer thickness. The time constant is about 0.2 My for a viscosity of 10^{23} Pa s. Local variation of elastic layer thickness is associated with inverse variation in deviatoric stress. In the elastic layer of an isostatically plateau uplift structure deviatoric stresses of over 100 MPa (1 kbar) can occur due to surface loading and compensating upthrust. Such a stress system provides a mechanism for continental splitting within this setting.

L38

LABORATORY MEASUREMENTS OF SEISMIC VELOCITIES AND ELECTRICAL RESISTIVITY OF ROCKS IN UPPER CRUSTAL CONDITIONS

P.N. Chroston, C. Evans and C. Lee, School of Environmental Sciences, University of East Anglia

Equipment has been developed at this University for measuring simultaneously seismic velocities and electrical conductivity of rock samples in upper crustal conditions. Confining pressure and pore water pressure can be varied up to 4 kb and temperature up to 300°C. In this paper we outline the results and discuss the implications of measurements made on some oceanic and on some (British) continental crust samples. Particular attention will be paid to the effects of temperature on P velocity.

L39

SEISMIC WAVE PROPAGATION IN ANISOTROPIC MEDIA: III IMPORTANCE FOR LITHOSPHERIC STUDIES

Stuart Crampin, Institute of Geological Sciences, Edinburgh

Detailed measurements of velocity anisotropy in the upper mantle can be interpreted in petrological terms. The method is limited by the difficulty of obtaining sufficient high-quality data. A more fruitful way of investigating upper mantle anisotropic structure appears to be by examining the polarization anomalies suggested by numerical calculations. These anomalies are very sensitive to even very weak anisotropy and may provide information about depth, thickness, orientation, and internal structure of any anisotropic layering. The implications of anisotropy in the upper mantle are discussed.

MAGNETOSPHERIC, IONOSPHERIC AND SOLAR-TERRESTRIAL

Aurora

M 1

ELECTRONS AND POSITIVE IONS ASSOCIATED WITH AN AURORAL ARC

D.A. Bryant, D.S. Hall, D.R. Lepine and R.W.N. Mason, Appleton Laboratory

Measurements of electrons and positive ions of 0.5 - 25 deV obtained on 21 November 1976 during the flight from Andoya in Norway of the first Skylark sounding rocket to reach an altitude of 715 km are employed to investigate the structure of an auroral arc and the processes that lead to its formation. It is shown that the arc was formed at the boundary between two source plasmas - to the south, the plasma sheet with electron and ion temperatures equivalent to 2 keV and 10 keV respectively; and to the north, the high-latitude magnetotail where the particles were less energetic. The arc appears to have been formed primarily by acceleration of electrons from the plasma sheet, though in some regions ions were accelerated apparently simultaneously. Field aligned currents carried by the energetic particles are evaluated.

M 2

IMAGE INTENSIFIED OBSERVATIONS OF AURORAL PULSATING PATCHES.

J. Crawford, P. Rothwell and R. Thomas.
Physics Department, University of Southampton.

An image intensifying isocon TV camera, fitted with an all sky lens, and an associated time lapse video recorder were used to make observations of auroral pulsating patches in Fairbanks, Alaska, in January 1976 and in Andoya, N. Norway, in November 1976. Pulsating patches occur after the break-up phase of an auroral substorm, equatorward of the discrete arcs, in the region of diffuse aurora. They are generally associated with VLF chorus emission and PC1 micropulsations. The pulsating patches, seen intensified on the TV screen, had a variety of distinctive forms which appeared to switch on and off as they drifted across the sky. The pulsation periods (typically a few seconds) and directions of drift of the various patches seen in the sky at any one time differed considerably. Estimates of the energy of the particles producing a particular patch could be made from the bounce period. Electric fields perpendicular to the magnetic field lines could be deduced from the drift velocities. The horizontal dimensions of the patches at auroral heights could also be estimated. The nature and the scale of the magnetospheric phenomena responsible for these observations will be discussed.

M 3

SUPRATHERMAL PARTICLE FLUXES ASSOCIATED WITH AN AURORAL ARC

A.D. Johnstone and J.J. Sojka Department of Physics and Astronomy, University College London

Preliminary results from suprathermal (5eV to 500eV) particle detectors on the first Skylark 12 firing, SL 1422, on 21 Nov 1976 are presented. The rocket was high enough at apogee (714 kms) to ensure that all but the lowest energies of particles with magnetospheric origin could be detected before interacting with the neutral atmosphere. Substantial fluxes of both electrons and protons, both upgoing and downcoming, were detected.

M 4

OBSERVATIONS OF PULSATING AURORA

D.J. McEwen, University of Saskatchewan, Canada
D.A. Bryant, Appleton Laboratory, Science Research Council

Pulsating auroras have been considered to be caused by very energetic electrons. The characteristic energy of electrons causing the optical pulsations, inferred from measurements of the intensities of 427.8, 557.7 and 630.0 nm emissions in pulsating aurora observed at Andoya, Norway in Nov. 1976, was much lower than predicted. One stable event with pulsations each 20 ± 2 sec was observed in the magnetic zenith. The pulsations were 0.5 kR above a 2 kR diffuse auroral background. They were apparently caused by 6 keV electrons while the diffuse aurora resulted from electrons of characteristic energy 3 keV. Accompanying TV all-sky pictures show the pulsations to be wave-like, appearing then travelling rapidly poleward.

These and other observations are discussed in relation to recent particle measurements in pulsating aurora.

M 5

ENERGISED AURORAL SUPRATHERMAL ELECTRONS

J.J.SOJKA and A.D.JOHNSTONE Department of Physics and Astronomy, University College London

The observation of field aligned suprathermal 'bursts' from several rockets flown through various forms of auroral activity gives a strong indication of the frequent presence of small scale electron energisation mechanisms. The electron signature of these subvisual auroral events being the enhancement of the field aligned electron flux component. This results in the electron spectrum having a bump in it at small pitch angles, somewhere in the suprathermal energy range. A study of electron data obtained below 250 km indicates that the mechanism is at times situated at these altitudes, while at others it extends above 700 km. The variable duration of the 'bursts' indicates that the mechanism is turbulent in both its spatial and temporal properties which probably implies that the ionospheric plasma over this region is near the limit of stability for this energisation mechanism.

M 6

INSTABILITY OF A FIELD-ALIGNED ELECTRON BEAM

R.J. Strangeway Blackett Laboratory, Imperial College, University of London

A previously published formulation for waves on a thin field-aligned electron beam of "Top Hat" profile is summarized. Solutions are sought between the background plasma hybrid frequencies. These are radiating modes except in a band between the electron gyrofrequency and plasma frequency in which ducted solutions exist. The minimum beam thickness is dependent on the mode which varies most rapidly across the beam, and is half the wavelength of this mode. The effect of parallel temperature on the beam thickness is investigated and found to be small. Various modifications to the model are possible and progress on an attempt to include perpendicular temperature is reported.

Aeronomy

M 7

ATOMIC OXYGEN IN THE MESOSPHERE AND LOWER THERMOSPHERE

P.H.G. Dickinson, Appleton Laboratory, Science Research Council

The current status of the Appleton Laboratory/University College of Wales, Aberystwyth programme of rocket borne measurements of atomic oxygen will be reviewed. In particular the analysis methods used to compare the concentrations on different occasions will be described. The results will be presented and the sources of error in the measurements will be discussed.
In addition a preliminary report will be given on the (at time of writing, proposed) S. Uist rocket campaign in February 1977.

M 8

THE SCATTERING OF SUNLIGHT FROM NOCTILUCENT CLOUDS

M. Gadsden, Department of Natural Philosophy, Aberdeen University, Aberdeen AB9 2UE

Determination of the sizes and shapes of the particles making up noctilucent clouds will probably be decided by observation of sunlight scattered from them. I consider the temperatures necessary for the clouds to form and the likely form of the ice crystals that will grow at these temperatures. Recent observational data support the hypothesis that the cloud particles are not only needle-like in shape but also show some preference in their orientation.

M 9

SOME CHARACTERISTICS OF CIRRUS CLOUDS OBSERVED WITH A STEERABLE LASER RADAR

A.J. Gibson L. Thomas and S.K. Bhattacharyya, Appleton Laboratory Slough

Measurements with a laser radar system in S.E. England have shown cirrus clouds (sometimes subvisible) to be present at 10-12 km on about 50% of otherwise clear nights. The measured backscatter and extinction coefficients of cirrus for different angles of elevation of the laser beam have been found inconsistent with models consisting of spherical or randomly-orientated irregular-shaped

particles. The results have been interpreted on the basis of a model of long cylindrical crystals orientated in a horizontal plane with arbitrary azimuthal angle, and show the importance of taking into account the directional dependence of the backscatter/extinction ratio in the interpretation and exploitation of laser radar data.

M10

NOCTILUCENT CLOUD MOVEMENTS

Alastair D Jenkins Department of Natural Philosophy, University of Aberdeen

Noctilucent clouds have been photographed from Aberdeen, with a 35 mm time-lapse motion-picture camera with effective focal length 610 mm and aperture f/4. The movements of the noctilucent clouds revealed by this system are discussed.

M11

ATMOSPHERIC WATER VAPOUR OF EXTRATERRESTRIAL ORIGIN

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The speculative suggestion that the influx of extraterrestrial hydrogen to the Earth's atmosphere constitutes a significant variable source of atmospheric water-vapour, which can be invoked to explain Sun-weather relationships, is examined in detail and found to be untenable. The continual influx of solar-flare protons with energies in the range 1-100 MeV makes an absolutely negligible contribution to the normal water-vapour concentration in the upper stratosphere and the mesosphere. The continuous influx at the magnetospheric clefts of solar-wind protons with a mean energy of about 1 keV, which cannot penetrate below 150 km and hence cannot form water vapour directly, only constitutes a highly-localized reduction, or reversal, of the global efflux of hydrogen atoms from the Earth's atmosphere. Other extraterrestrial sources of atmospheric water vapour or atomic hydrogen are also insignificant.

M12

THEORY OF THE NEAR INFRA-RED NIGHTGLOW CONTINUUM.

P.C.Wraight, Department of Natural Philosophy, Aberdeen University, Aberdeen AB9 2UE.

Observations are reviewed which indicate that there is a component in the night-glow continuum which rises in intensity from near 0.6μ to 1.0μ. It is suggested that the source of this continuum is radiative association of atomic oxygen to the ground state via the (largely repulsive) $^3\Pi_u$ state. Model calculations indicate qualitative agreement with observation. There is also support from laboratory measurements. Implications for the physics of the lower thermosphere are discussed.

Ionosphere and Movements

M13

RELATIVE FLOW OF H^+ AND O^+ IONS IN THE TOPSIDE IONOSPHERE AT MID-LATITUDES

R.J. Moffett and G.J. Bailey Department of Applied Maths. and Comp. Sc., University of Sheffield
J.A. Murphy Department of Mathematics, University of Aston in Birmingham

Theoretical results on the daily variation of H^+ and O^+ field-aligned velocities in the topside ionosphere are presented. The results are for an L=3 magnetic field tube under sunspot minimum conditions at equinox. They come from calculations of time-dependent H^+ and O^+ continuity and momentum balance in a magnetic field tube which extends from the lower F2-region to the equatorial plane. The magnitude of the ion velocity difference is such that significant heat flow may be induced in the ion gases, as suggested by St. - Maurice and Schunk. There are occasions when ion counterstreaming occurs, with the O^+ velocity upward and H^+ velocity downward, as observed at Arecibo by Vickrey, Swartz and Farley. The conditions causing this counterstreaming are described.

M14

T_i TROUGHS IN THE EQUATORIAL TOPSIDE IONOSPHERE

H. Rishbeth, Appleton Laboratory, Slough

The ion-trap aboard OGO-6 recorded marked depressions of ion temperature on certain occasions as the satellite crossed the magnetic equatorial region

at heights of 700 - 1100 km. These T_i troughs are about 40° wide in latitude and up to 1200 K in depth; their occurrence varies with longitude, LT and season. They are attributed to adiabatic cooling of F-region plasma driven along geomagnetic field lines by trans-equatorial winds. The directions of these winds, as deduced from current thermospheric models, is consistent with the occurrence of the T_i troughs. (Co-operative project with University of Texas at Dallas and NOAA, Boulder, Colorado.)

Magnetosphere

M15

OUTER RADIATION ZONE STRUCTURE IN A SIMPLE MAGNETOSPHERIC MODEL

S.W.H. Cowley Blackett Laboratory, Imperial College

The structure of the outer radiation zone has been calculated using the simplest steady-state model of the convecting magnetosphere (dipole magnetic field plus uniform convection electric field). The development of anisotropies in the plasma will be discussed in relation to microinstabilities, together with the variation of plasma bulk parameters with L and the effects of the forbidden zones (Alfvén layers). Particular emphasis will be placed on the proton 'nose' structures observed by Explorer 45. It has been found that the inclusion of strong proton losses is necessary to reconcile the model with observations.

M16

RECENT RESULTS ON MAGNETIC MERGING IN COLLISIONLESS PLASMAS

S.W.H. Cowley Blackett Laboratory, Imperial College

The properties of one-dimensional steady-state current sheets in a collisionless plasma will be discussed, using analytical models based on Eastwood's (1972, 1974) numerical results. The problem of maintaining charge neutrality in the current layer will be emphasized. It is shown that there exists no solutions of this problem in which particles remain adiabatic in the current layer. The relevance of the results of this study to the properties of collision-free X-type systems will also be discussed.

M17

HYDROMAGNETIC EIGENMODES IN A SIMPLE MODEL PLASMASPHERE WITH A THIN LOWER IONOSPHERE

A.H. Craven and J.A. Lawrie, Mathematics Division, University of Sussex.

Damped hydromagnetic eigenmodes have been calculated for a simple model plasmasphere with a thin lower ionosphere. Further toroidal solutions have been calculated with spatial attenuation transverse to the magnetic field lines; but steady state solutions have not been obtained. If steady state toroidal solutions do exist, they appear to be strongly attenuated.

M18

LOCALISED Pc 4's WHICH OCCUR AT HIGH LATITUDES IN THE MIDNIGHT-DAWN QUADRANT

C. A. Green and W. F. Stuart Institute of Geological Sciences, Edinburgh

Packets of peculiarly highly coherent Pc 4 occur at Kiruna and Tromso. They occur predominantly in the midnight-dawn time sector with a maximum occurrence between local midnight and 03.00. Their period range is 80 to 150 seconds and were previously classified P_G.

Relative amplitude of the vertical component is shown to relate to period range and appears to be in agreement with generation by a highly localised field line resonance. Phase and Polarisation characteristics are discussed together with the relationship of these pulsations to night time magnetospheric conditions.

M19

POSSIBLE EFFECTS OF I.M.F. SECTOR POLARITY ON S_q

J. G. Greener and D. M. Schlapp, Department of Physics, University of Exeter.

Previous workers have suggested that in addition to the well-established effects in polar regions, there is some control of midlatitude S_q by the I.M.F. Some results are presented based on daily ranges for a number of Northern hemisphere stations. The statistical significance of the results is marginal but if the effect is real, its sign

appears to change from year to year and season to season.

M20

A Pc 4 PULSATION OBSERVED NEAR MIDNIGHT AT GEOSTATIONARY ORBIT

W.J. Hughes Blackett Laboratory, Imperial College, University of London
R.L. McPherron Institute of Geophysics and Planetary Physics, University of California, Los Angeles
J.N. Barfield, Space Environment Laboratory, National Oceanic and Atmospheric Administration

We describe the observation and analysis of a narrow band continuous geomagnetic pulsation of about 60s period (Pc 4). The observation was made by three geostationary satellites with a total longitudinal separation of 20°, located just prior to local midnight. The pulsation lasted for about 90 minutes and had a large compressional magnetic field component. It was found that the signals were not coherent over the whole satellite array which indicates a rapid azimuthal phase variation. This pulsation is unusual because of (a) its occurrence near local midnight when continuous pulsations are not normally observed and (b) the very monochromatic nature of the signal. The implications of this event will be discussed in the light of theory.

M21

FOCUSING OF WHISTLERS BY A VARYING MAGNETIC FIELD

M.J.Laird Department of Mathematics, King's College, London

We consider the propagation of whistlers when the ambient magnetic field $\underline{H}$ is a function only of the x coordinate. We examine ray paths from a source at the origin, where H_y and H_z are taken to vanish, and discuss the focusing of rays with small initial wave-normal angle, and the associated caustic surface. We show that for a wave frequency equal to half the electron gyrofrequency at the origin, there is a ray path along the field line. The theory is related to recent observations of magnetospheric chorus.

M22

SOURCES OF DAMPING OF Pc's

R.S. Newton Blackett Laboratory, Imperial College, University of London

Ionospheric damping of continuous pulsations is considered with the aid of numerical solutions of the uncoupled poloidal mode. The program assumes a dipole field and the ionospheric boundary condition $4\pi\Sigma_p E/c = b$ where E and b are field perturbations and Σ_p is a height integrated conductivity. A density model of $\rho \propto L^{-4}$ is used. The relationship between damping rate and Σ_p is studied. Typically, for a dayside value of conductivity the damping rate is found to be weak (e.g. $\gamma/\omega \sim 10^{-3}$), whilst for a nightside value the damping rate is more severe (e.g. $\gamma/\omega \sim 10^{-1}$). Collisionless damping by interaction with resonant particles is also discussed as is the asymmetric case of different ionospheric conductivities at either end of a field line.

M23

THE ROLE OF HOT PLASMA IN MAGNETOSPHERIC CONVECTION

D.J. Southwood, Blackett Laboratory, Imperial College, University of London

Several authors have earlier shown that the presence of hot plasma in the magnetosphere can severely modify an imposed convection pattern and even prevent its penetration to low latitudes. Here it is argued that the important parameters governing such effects are hot particle pressure, number density and the ionospheric conductivity with the result that the shielding phenomenon can be pictured in a fluid manner. Such a description is given. The effects of ring current pressure on ring current injection are discussed in the fluid picture. The limitations of the fluid approximation, the development of steady state flow patterns and the effects of collisionless plasma behaviour are qualitatively described with the aid of simple theoretical models. The role of particle loss is also discussed.

M24

PARTICLE FLUX VARIATIONS PRODUCED BY MAGNETOSPHERIC HYDROMAGNETIC WAVES

D.J. Southwood Blackett Laboratory, Imperial College, University of London

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Magnetospheric hydromagnetic waves generally produce flux variations in energetic particle distributions. Potentially these oscillations can yield information on wave modes. We show that the oscillation amplitude is strongly dependent on the particle energy, the background particle distribution, the symmetry of the wave disturbance and its wavelength by examining theory. Examples of observations from the spacecraft OGO5 and ATS6 are discussed.

M25

SOME GLOBAL CHARACTERISTICS OF PULSATION ACTIVITY

W. F. Stuart and C. A. Green Institute of Geological Sciences, Edinburgh

From a preliminary scruting of pulsation recordings made in Newfoundland, UK, and Scandinavia examples are shown which illustrate some aspects of the global morphology of pulsation activity. Simultaneous 'switch on' and 'off' of pulsations over a large global area is demonstrated and the range of coherence of pulsation signals over 6 hours of local time is discussed. Variation of N-S and E-W characteristics of Pi 2's are shown to be dependent on, among other things, the degree of impulsiveness in the apparent stimulus.

M26

SECONDARY RESONANCE IN Pi 2's

W.F. Stuart and Paul M. Mills Institute of Geological Sciences, Edinburgh

Characteristics of the mid-latitude resonance in Pi 2's appears to indicate that in the pre- midnight sector it occurs within the plasmapause and that past midnight the resonance is outside the plasmapause. Spectral studies show that mid latitude Pi 2's have no systematic latitude dependence of period.

Impulsive Pi 2's (dPi's) have several spectral components and these cases appear to support the interpretation of monochromatic Pi 2's as being due to field line resonance. Possible implications about source characteristics are discussed.

M27

LONG PERIOD CONTINUOUS PULSATIONS AT HIGH LATITUDES

M.R. Warner and D. Orr Department of Physics, University of York

High latitude geomagnetic field lines differ significantly from a dipole geometry. Time of flight calculations using the Mead-Fairfield model of the geomagnetic field are presented. Ground based observations of long period Pc 4 and Pc 5 pulsations support the suggestion that some of these waves are guided hydromagnetic waves in the plasmatrough. The location and period of the waves are consistent with an association with regions of enhanced proton density (detached plasma).

M28

A COMPARISON OF ULF AND VLF MEASUREMENTS OF MAGNETOSPHERIC COLD PLASMA DENSITIES

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C.G. Park Radioscience Laboratory, Stanford University

Equatorial cold plasma density profiles determined from VLF whistlers propagating in magnetospheric ducts are compared with densities computed from the observations of ULF hydromagnetic waves (geomagnetic pulsations). The densities obtained by the ULF technique, are based on the identification of resonant geomagnetic field lines, assumed to be driven by a monochromatic source. The ULF results thus obtained agree well with the whistler results throughout the period, June 17-20, 1973. The ULF observations show that at mid-latitudes shorter period resonances can be supported in the plasma trough region, while those of longer period can occur inside the plasmasphere.

M29

TEMPORAL VARIATIONS IN TOTAL EQUATORIAL PLASMASPHERIC CONTENT AND THEIR RELATIONSHIP TO THE RING CURRENT INTENSITY AND THE PLASMAPAUSE

D.C. Webb Department of Physics, University of York
L.J. Lanzerotti Bell Laboratories, New Jersey

Measurements of the plasmaspheric electron content (N_p) as monitored by the ATS 6 Radio Beacon Experiment during the interval July 1974-May 1975 have been used to study the effects of ring current intensity and geomagnetic storms on the plasmasphere. Values of N_p measured at local midday are compared with values of two geomagnetic indices Dst and Kp. At geomagnetically active times when the plasmasphere has been eroded and the plasmapause has moved close to the earth, different models of equatorial plasma distrubution, varying as R^{-n} are used to compute a value for the plasmapause position. Reasonable values of the plasmapause position are found if it is assumed that the plasma density at 1000 kms varies in direct proportion to the plasmapause position.

Interplanetary

M30

STOCHASTIC AND DYNAMIC TEMPERATURE CHANGES IN THE INTERPLANETARY GAS

Max K. Wallis, Mathematical Institute, Oxford University
M.A. Hassan, Department of Mathematics, University of Khartoum, Sudan

Exact solutions of the Fokker-Planck equation representing stochastic velocity changes have been found, to describe particles moving in an inverse square central force field under an inverse square collision frequency. The solutions for velocity distribution contain a combination of collisional and dynamical heating. At a general position there are two populations each with three distinct temperatures. Interplanetary helium gas that reaches around 1 AU in the downstream wake, where the density is enhanced through the gravitational lens effect, is heated by several 100°K; that population reaching 1 AU from the sun perpendicular to the initial direction along indirect orbits is heated to several 1000°K. In the interpretation of sky background radiation observations, these effects have to be carefully considered. The purely dynamical changes in the velocity spread have also to be taken into account for hotter helium gas, for which Doppler shifts relative to the solar emission line are significant. As the background Lyman-α radiation is conditioned by heating of the approaching hydrogen gas outside the heliosphere, current determinations of local interstellar gas parameters are most uncertain.

PLANETOLOGY

P 1

MICROMETEORITE AND SOLAR WIND EROSION OF THE LUNAR SURFACE

D.G. Ashworth Electronics Laboratories, University of Kent at Canterbury, Kent.

Current lunar crater production and equilibrium distribution curves are reviewed. Equilibrium distribution curves, lunar crater erosion rates, and rock lifetimes on the lunar surface are derived from the production curves by using proven analytical techniques. It is shown that the equilibrium curves are in good agreement with equilibrium distributions measured on lunar rocks and with other statistically derived distributions. The predicted erosion rates on the lunar surface are also in very good agreement with erosion measurements made on typical lunar rocks. It is shown that ambiguity still exists between the curves derived from lunar rock crater counts and those derived from satellite measurements.

P 2

EVAPORATIVE SOURCES FOR TRACE COMPONENTS OF PLANETARY ATMOSPHERES

Peter Brimblecombe and Keith Hunter, School of Environmental Sciences, University of East Anglia, Norwich

Evaporation of substances into atmospheres from planetary surfaces is usually considered only for those substances, such as liquids or ices which are volatile in terms of terrestrial experience. Recently it has been suggested that some trace heavy metals found in the Earth's atmosphere might be present due to the evaporation of such non-volatile compounds as metal oxides or sulphides. Determination of the magnitude of contributions from evaporation is hampered by the lack of vapour pressure data for minerals of interest, particularly at relatively low temperatures, and is further complicated by the effects of the matrices within which they are present. However it is clear that evaporation rates which may be quite high under a vacuum are lowered by boundary layer effects when an atmosphere is present. Evaporation of minerals can thus be expected to make more significant contributions in very tenuous atmospheres. The contribution that evaporation of surface minerals is likely to make to the atmosphere of the planet Mercury is considered in more detail.

P 3

TOWARDS A NEW SEMI-LITERAL THEORY OF THE LUNAR LIBRATIONS

A.H. Cook, Department of Physics, University of Cambridge

A brief account will be given of progress in the development of a new theory of the lunar librations, in which a computer system of algebraic manipulation (CAMAL) is used to develop algebraic expressions.

P 4

DETERMINATION OF THE TEMPERATURE AND DURATION OF SOME APOLLO 17 BOULDER SHADOWS USING THERMOLUMINESCENCE METHODS

S.A. Durrani Department of Physics, University of Birmingham

The natural thermoluminescence (TL) retained by soil samples collected from the shadows of certain Apollo 17 boulders has been compared with that of a nearby sunlit sample. The shaded samples have been kept continuously refrigerated, since soon after their retrieval, to preserve their natural TL. By experimentally determining the various TL parameters of the relevant trapping levels, we have attempted to calculate the temperature (T_1) in the shade and the duration (t_1) of the shadow cast on the samples. We obtain the values T_1 = 256K and t_1 $\sim 4.0 \times 10^4$ - 5.7×10^4 yr, based on a dose-rate of 10 rad yr^{-1} in the shade. On applying various corrections for the fading of the natural TL over the intervening $\sim$3 yr, a value of t_1 $\sim 6.5 \times 10^4$ yr is obtained. These values of the storage time in the shade confirm the relatively recent arrival of the boulder concerned at its present location, as was indicated by the freshness of its tracks.

P 5

LARGE SCALE PROCESSES ON THE MOON

G. Fielder, Lunar and Planetary Unit,
Department of Environmental Sciences,
University of Lancaster

Recent research on the viscous dissipation mechanism involved in the gravitational adjustment of geological structures has lent new weight to the dualistic hypothesis of the formation and development of certain large lunar craters. The craters in question - distinct from those which are essentially of impact origin and from those which are purely volcanic in origin - have suffered protracted developments involving volcanic activity preceded, millions of years earlier, by major collisions. Consideration is given to the application of this hypothesis to the problem of the origin of Mare Inbrium, using rock ages from the Apollo programme.

P 6

THE FIRST 100 MILLION YEARS

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University.

Three major classes of events which occurred within the first 100 million years of Solar System history can now be accurately dated by radiometric methods. They are; the formation and thermal metamorphism of primitive solid objects (chondrites), magmatic processes caused by an undetermined heat source and producing chemically differentiated objects (achondrites, irons) and, high velocity collisions producing fragmented bodies (breccias). Recent advances in our understanding of the relative and absolute times of these events will be presented.

SEISMOLOGY

Earthquake Source and Transmission Path

S1

SCATTERING AT THE 650KM BOUNDARY

B.J. Barley, MOD(PE), Blacknest, Brimpton, Reading RG7 4RS, Berks

Complexity and simplicity of the P seismograms of eleven deep earthquakes in the Izu-Bonin Is., observed at the medium aperture seismic array Warramunga, Australia ($49 < \Delta < 53$), correlate with negative and positive m_b residuals (measured-expected) respectively. The negative m_b residuals are attributed to direct P leaving the focal sphere close to a node of P. An association between negative m_b residuals and complexity is expected if scattered energy in the coda remains fairly constant in amplitude as the absolute P amplitude falls due to the radiation pattern. This background energy might be produced by scattering of S to P; this hypothesis is supported by five observations of a high frequency (1-2Hz) emergent phase arriving about 30s after P, which is coherent across Warramunga, has $dT/d\Delta$ and arrival azimuth close to P, and a variation of arrival time with hypocentral depth consistent with S to P scattering at a rough interface between 650 and 700km beneath the Izu-Bonin Is.

S2

SEISMIC WAVE PROPAGATION IN ANISOTROPIC MEDIA: I COMPUTATIONS

Stuart Crampin, Institute of Geological Sciences, Edinburgh

Propagation of seismic waves in anisotropic media is fundamentally different from that in isotropic solids, although the effects may be subtle and easily overlooked. Coupling between sagittal and horizontal transverse motion writes anomalous signatures on the seismogram. These are illustrated by numerical computations from models containing anisotropy in the upper mantle. Most surface waves show very few effects except for the Third Generalized mode (equivalent to the isotropic Second Rayleigh mode), which has distinctive and diagnostic coupling. Incident P waves have anomalous SH arrivals after the S-P delay through the crust. Incident SV (or SH) waves may have almost equal amplitude SH (or SV) components.

S3

SEISMIC WAVE PROPAGATION IN ANISOTROPIC MEDIA: II OBSERVATIONS

Stuart Crampin, Institute of Geological Sciences, Edinburgh

Seismic anisotropy in the oceanic upper mantle has been recognised since 1964. There are now two observations of seismic anisotropy in the upper mantle beneath Eurasia: Bamford (1977) has found 7% velocity anisotropy beneath the Rhinegraben, and Crampin and King (1977) have observed diagnostic coupling of the Third Generalized mode indicating aligned anisotropy beneath the whole of the Russian Shield area. Unfortunately, these surface wave studies have not yielded a direction of symmetry, but do suggest that the orientation of the anisotropic symmetry changes only gradually over Eurasia.

S4

SEISMOLOGY IN THE OCEANIC MICROSEISM BAND

A. Douglas MOD(PE), Blacknest, Brimpton Nr Reading, Berks, RG7 4RS

To demonstrate the advantages of broad band recording, the seismic body wave signals from a series of earthquakes and explosions as recorded on conventional narrow band short period and long period seismographs are compared to the same signals recorded on a broad band seismograph (with displacement amplitude response flat from about 0.1 to 10.0Hz). When the broad band signal is recorded with adequate signal to noise then: (1) the shape of the pulses radiated by the seismic source can be observed directly; (2) the surface reflections such as pP and sP are more easily identified than on narrow band records; and (3) the polarity and onset time of arrivals can be read with less possibility of error than on narrow band records.

The biggest drawback to broad band recording is the very high noise levels that are usually present in the band 0.125Hz-0.167Hz the so-called oceanic microseism band. These noise amplitudes may be so large as to swamp all but the very largest signals. Fortunately much

of this noise is often propagating as coherent wave trains and array processing can be used to reduce these coherent components virtually to zero. Examples are shown of the application of array processing methods to broad band recordings to obtain the best estimates of signals in the presence of noise with both random and coherent components.

S5

EARTHQUAKE SYNTHESIS

Khalid J. Fahmi Dept of Geophysics, University of Edinburgh and the Institute of Geological Sciences Edinburgh

An attempt is made to take account of the effect of a "design earthquake" anticipated to occur in a seismically and tectonically active area. One way of achieving this aim would be to try to predict the waveform of a large event before it occurs. This can be done by the simple addition - after introducing the necessary time delays - of microtremor records, enough in quantity and of the desired quality to sample the whole source region of a major earthquake. By the application of this summation procedure it is expected that the destructive interference of high frequencies and the concomitant build-up in low frequencies and in wavepattern, would transform the waveform of the microtremors into an approximation to that of the large event.

S6

OCEAN BOTTOM SEISMOGRAPH OBSERVATIONS NEAR THE EASTERN END OF THE ST. PAUL'S FRACTURE ZONE

T.J.G. Francis, I.T. Porter and R.C. Lilwall, Institute of Oceanographic Sciences, Blacknest

An array of four OBS was operated in late 1974 near the junction of the St. Paul's Fracture Zone with the median valley of the Mid-Atlantic Ridge to the south. Earthquakes were detected both on the Fracture Zone and in the median valley. Many events occurred close to or within the confines of the array and for these precise focal depths have been obtained. The tectonic significance of the distribution of epicentres and focal depths obtained will be discussed.

S7

THE STRUCTURE OF SEISMIC SCATTERED WAVES

J.A. Hudson and J.R. Heritage, Department of Applied Mathematics and Theoretical Physics, University of Cambridge

The first part of the paper consists of an investigation of the conditions under which first-order scattering theory may be regarded as reliable as a method of predicting the amplitudes and shapes of waves scattered from heterogeneities in the Earth. The second part concerns the expressions for scattered wave displacements, and, in particular, the effect of wavelength and the relationship with calculations from ray theory.

S8

A NEW APPROACH TO SURFACE WAVE DISPERSION

N.J. Kerry and B.L.N. Kennett Department of Applied Mathematics and Theoretical Physics, University of Cambridge

A new approach to the calculation of surface wave dispersion has been devised based on the determination of the reflection response of an elastic half space. The new technique is computationally very convenient and appears to be competitive with the fastest existing methods.

S9

COMPUTED CHARACTERISTICS OF SEISMIC SURFACE WAVES FOR ANISOTROPIC MODELS OF OCEANIC STRUCTURE

S. Kirkwood, Department of Geophysics, University of Edinburgh

Dispersion and particle motion characteristics have been computed for the first four normal modes of surface wave propagation in plane-layered models where at least one layer is anisotropic and the surface layer is liquid. Results suggest that even large amounts of anisotropy in the uppermost mantle would not alter the fundamental Rayleigh mode significantly. Anomalous particle motion, with coupled radial and transverse components, is likely for modes corresponding to isotropic higher Rayleigh modes and is possible, with coupled transverse and vertical components, for modes corresponding to isotropic fundamental and higher Love

modes. Only small azimuthal variations of phase velocity are likely for fundamental Rayleigh or Love modes.

S10

OCEAN BOTTOM SEISMOGRAPH OBSERVATIONS ON THE MID ATLANTIC RIDGE AT 45°N

R.C. Lilwall, T.J.G. Francis, and I.T. Porter, Institute of Oceanographic Sciences, Blacknest

Seismicity at 45°N appears to be restricted to a zone only 5km wide. Epicentres determined from teleseismic data can be reconciled with this zone. Both swarm like and aftershock type sequences were observed all with similar b values. The b value for teleseismically observed events is greater but this difference can be explained by differences in the magnitude scales employed. The observations are in agreement with a Caldera collapse model of the Median Valley with movement restricted to the inner faults.

S11

IS P_n VELOCITY AN INDICATOR OF Q_α

P.D. Marshall, MOD(PE), Blacknest, Brimpton, Reading, Berks RG7 4RS

An empirical relationship between the velocity of P_n and amplitude residuals has been established for N. America. As it seems reasonable to suppose that the amplitude variations are caused by Q_α variations it is concluded that Q_α and the velocity of P_n are correlated.

S12

FAULT PLANE SOLUTIONS USING P AND pP RELATIVE AMPLITUDES

R.G. Pearce, School of Physics, University of Newcastle Upon Tyne (and Blacknest)

P wave polarity observations sample only a small fraction of the information contained in seismograms. Comparison of observed and theoretical seismograms for shallow earthquakes has confirmed that there are other features of P wave codas which are sensitive to source orientation, notably the relative amplitudes of P and the surface reflections pP and sP. Here this information is utilized in a new method of computing fault plane solutions. The procedure is demonstrated using earthquakes with m_b as low as 5.0. While the method enables double couple solutions to be computed using only a few seismograms, the inclusion of many stations imposes strict limitations on the source radiation pattern, and so provides a means of testing different mechanisms against observation.

Instrumentation and Networks

S13

AN EXPERIMENT WITH A UK SEISMOLOGICAL DATA CENTRE

F. H. Grover PE/MOD Blacknest, Brimpton, Near Reading, Berkshire

A basic objective of the experiment has been to evaluate methods of monitoring international compliance with a possible comprehensive nuclear Test Ban Treaty. Using data supplied by a seismometer array station in the UK and 3 other arrays overseas, with which long-standing liaison for R&D studies already existed, it has been possible to make a pilot study of an operational monitoring system based on a small but well-distributed network.

Important features of the experiment have been improvement of communications to provide rapid and regular flow of data, establishment of data exchange links with other centres, strengthening the data contribution from within the UK and the creation of a database on computer files to which collaborating centres may have access.

S14

A SEISMIC NETWORK IN IRELAND

A.W.B. Jacob, T. Murphy and G. Wallace, Dublin Institute for Advanced Studies

A triangular seismic network is being established in Ireland. This includes a recorder at a site near Dublin and two radio-linked outstations, the pattern being an equilateral triangle of side about 50 km. All stations will have both broad-band and high-gain short period instrumentation. Sites are required which have (1) low general background noise levels and (2) low

signal generated noise levels. Site testing is being carried out and results from this are presented.

S15

CWF - A SEISMIC STATION IN THE MIDLANDS

P.K.H. Maguire Department of Geology, University of Leicester

A permanent, three component, short period seismic station CWF, has been installed on the Precambrian volcanics of Charnwood Forest. Signals are recorded on a multichannel, slow speed tape recorder, the Geostore. Although situated only 1.8 km from a major motorway, and about 4 km from four industrial towns, noise levels are low, typically 10-15 nm during the week, falling to half that value at weekends. The station was operational from October 1974 to April 1975, and then from October 1975 to the present. For five months during the winter of 1975-6, it was supplemented by seven other stations forming a small, 5 km aperture array. Arrivals were obtained from blasts at 11 quarries, whose shot instants were timed. Following the dismantling of the array, CWF has proved valuable in estimating shot times of untimed quarry blasts recorded on two seismic projects in the vicinity of Charnwood. As well as quarry blasts (50-100 each week) 423 regional and teleseismic events have been picked from CWF records. From analysis of a selective set of events, there appears to be considerable azimuthal variation in the P - wave delay relative to Eskdalemuir, ESK. Between 350 to 140 degrees, all the measured delays are negative at CWF relative to ESK with a mean of -0.26 $\pm$ 0.05 secs. Between 250 and 320 degrees the relative delay is positive. Seven of these events are from the Nevada test site giving a relative delay of +0.65 $\pm$ 0.05 secs. From the available data, the delay does not appear to vary with distance.

S16

DEVELOPMENT OF MINIATURE WIDE-BAND FORCE-BALANCE SEISMOMETERS

M.J. Usher, Department of Engineering and Cybernetics, University of Reading, Berks

Conventional seismometers employ masses of several kilogrammes suspended with periods of several seconds, but it is possible to achieve the same detection capability with much smaller masses suspended at shorter periods. Such instruments are valuable for borehole applications or where many instruments must be rapidly set up.

The problems of the design of miniature wide-band force-feedback seismometers are discussed and two such instruments are described. Both instruments use a capacitive displacement transducer to detect the displacement of a mass of about 50gm having a natural period near one second. A force-feedback system maintains the mass stationary with respect to the instrument frame and the device has an output flat to acceleration from dc to 10Hz. A single miniature instrument can thus provide data over the whole of the seismic range.

Details are given of the experimental difficulties encountered and of a comparison of the instruments with conventional seismometers.

S17

RECENT DEVELOPMENTS IN PORTABLE SEISMOGRAPH EQUIPMENT

P.L. Willmore IGS, Global Seismology Unit, Edinburgh

The options available for field work in earthquake seismology have been extended in several directions. The first is an electronic feedback system which can increase the natural period of Willmore Mark III seismometers to about 50 secs. The second is a modification to the control circuitry of Racal-Thermionic magnetic tape recorders to permit single-channel operation for up to 7 months without change of tape. The third is a miniaturised smoked-film recorder which can produce a transparency, having resolution comparable to that of a 70-mm film chip, from a battery-powered package measuring only 240mm x 120mm x 100mm

Seismic Risk

S18

INDUCED SEISMICITY IN THE UNITED KINGDOM

C.W.A.Browitt Global Seismology Unit, Institute of Geological Sciences, Edinburgh

In recent years there has been an increasing awareness that man is capable of modifying the environment to such an

extent that the seismicity of an area is changed. There are implications for the United Kingdom in the fields of reservoir impounding, fluid injection and mining. The latter has recently been shown to be a triggering activity in two UK coalfields with the largest induced event of damaging intensity. A comparison of the two cases is presented and the importance of macroseismic data in a sparsely instrumented country is demonstrated.

S19

SEISMICITY AND ASSOCIATED RISK IN THE UNITED KINGDOM

Paul W Burton, Global Seismology Unit, Institute of Geological Sciences, EDINBURGH

The results of a seismic risk analysis in a region of relatively low activity like the United Kingdom necessarily largely depend on historical catalogues of earthquakes with whatever inaccuracies these contain. Nevertheless it is possible to mitigate against the effects of incompleteness in the macroseismic sample and variability in the human population by using extreme value analysis. The ensuing results for return period analysis at given magnitude levels allow the estimation of the magnitude of those naturally occurring earthquakes which are likely to be seriously damaging in the United Kingdom. With this information from historical data it is then possible to examine the ground motion characteristics of more recent and instrumentally recorded earthquakes which are in this magnitude range.

S 20

EARTHQUAKE PARAMETERS FROM EXTREME VALUE STATISTICS

Costas Makropoulos Department of Geophysics, Edinburgh University and the Institute of Geological Sciences, Edinburgh.
Paul W Burton Global Seismology Unit, Institute of Geological Sciences, Edinburgh.

The application of extreme value statistics to the analysis of seismicity is discussed and the paper presents results for both the circum-Pacific and Greece. It is shown that Gumbel's third assymptotic distribution gives an excellent and informative fit to the data. Values obtained for the parameter specifying the upper limit to the earthquake magnitude in several regions are presented, and the magnitude assigned to a large historical earthquake in Greece is reassessed. A simple empirical relation is obtained between the Gumbel parameters and the annual strain release for a region.

S21

MICROZONING IN SPACE AND TIME

P.L. Willmore IGS Global Seismology Unit Edinburgh

Conventional seismic zoning starts with a historical pattern of earthquake occurrence in a seismic region, and computes therefrom the expected distribution of earth-motion parameters on the assumption of uniform attenuation throughout the region and of stationary statistical expectation of earthquake occurrence. Microzoning seeks to determine variations in attenuation over the affected region, with particular reference to near-surface effects which can introduce repeatable anomalies into the zoning map. Prediction is the end-point in the process of recognising non-stationary features in the pattern of regional seismicity, but useful results can be obtained at an earlier stage in the recognition of time variations in the rate of strain release. Concerted IGS effort is directed towards the ultimate goal of producing "design seismograms", with expectation of occurrance, tailored for a particular structure on a particular site.

Regional Studies

S22

SEISMICITY OF THE SOUTH SANDWICH ISLANDS REGION

C.P. Brett, Department of Geological Sciences, University of Birmingham

South Sandwich Island earthquakes have been relocated for the period 1964 - mid 1974. Travel-times modified by station corrections, computed by applying the joint epicentre method to the major events, have been used. This results in the definition of the active zone, arising from the subduction of the South American plate beneath the young Sandwich plate, being greatly improved. The

detailed features of the seismicity are interpreted in terms of the tectonics of the area, and new evidence is presented which suggests that the penetration depth of the subducted slab may be deeper than previously recognised.

S23

LATERAL VARIATIONS OF P-WAVE VELOCITY STRUCTURE WITHIN THE EURASIAN REGION

P.C. England Department of Geodesy and Geophysics, Madingley Rise, Cambridge. M.H. Worthington Department of Geology and Mineralogy, Parks Road, Oxford.

T-Δ curves have been obtained for P-waves arriving at the Norwegian Seismic Array in three different azimuth ranges. These are: 40-120°, 120-200° and 250-20° for rays bottoming under Western Russia, southeast and central Europe and the North Atlantic ocean and continental margins, respectively. These three regions yield travel time curves of significantly different character and indicate appreciable variations in velocity structure within the region to depths greater than 400 km.

S24

TELESEISMIC DELAY TIMES, BOUGUER ANOMALIES AND INFERRED THICKNESS OF THE AFRICAN LITHOSPHERE

J.D. Fairhead, Department of Earth Sciences, University of Leeds

Teleseismic P-wave travel time residuals (delay times) have been determined for 38 African seismograph stations using a total of 104 Russian underground nuclear explosions, 92 from East Kazakhstan and 12 from Novaya Zemlya. The delay times (T) for seismograph stations situated on Precambrian crust within the interior of Africa, where surface erosion is minimal, appear to be linearly related to both stations elevation (E) and Bouguer anomaly (B) such that $T = (1.12 \pm 0.32) E - (1.81 \pm 0.44)$ .. (1), $T = (0.012 \pm 0.005)B - (1.81 \pm 0.60)$ (2), where T is in seconds E in kilometres and B in milligals. Equation 2 has been used to predict delay times more generally over Africa using the Bouguer anomaly map of Slettene et al. Although previous gravity studies have shown the African crust is in approximate isostatic equilibrium, the above relationships cannot be explained purely in terms of Airy-Heiskanen isostasy. The variations in delay times are thus considered to arise from structures within the upper mantle. One possible source is lateral variations in thickness of the asthenosphere which is assumed in this study to manifest itself as a variation in thickness of the overlying lithosphere. The delay time map is tentatively used to derive a map of lithosphere thickness which takes into account lateral variations of velocity within both the lithosphere and asthenosphere. The lithosphere thickness model indicates a major zone of thin lithosphere (thick asthenosphere) is associated with the East African Rift System and its continuation into southern Africa. Concomitant seismicity, volcanism and high heat flow further suggest that incipient separation of the continental plate is taking place along the axis of this zone.

S25

DETERMINATIONS OF Q_α FOR DIRECT PATHS FROM THE URALS TO THE UK.

R.W. Hurley, MOD(PE), Blacknest, Brimpton Reading, RG7 4RS

Q_α is estimated for direct body wave paths from the Urals to the UK using P to PcP ratios. An attempt to segment the paths according to their Q contribution is presented.

S26

RESONANCES IN MICROSEISMIC NOISE SPECTRA

D T Meldrum, Scott Polar Research Institute, University of Cambridge

A simple experiment is described whereby the seismic background noise at a variety of sites was measured. The amplitude spectra of the records made on top of a large sill show strong peaks in the 1-100 Hz band which are substantially absent at other nearby sites. It is shown that these peaks are consistent with the normal modes of a simple model of the sill, and a value for its thickness is derived which is in reasonable agreement with other observations. Alternative explanations are also discussed.

S27

A SURFACE WAVE STUDY OF THE STURCTURE OF THE NORTH SEA AND SCANDINAVIA.

G.W. Stuart, Department of Earth Sciences University of Leeds

The variation in the shear wave velocity structure of the crust and upper mantle (surface to 400km) of North-West Europe is determined from the phase velocity dispersion of fundamental Rayleigh waves along profiles between the WWSSN stations of ESK, COP, KON, UME, NUR and KEV. Inversions of the regional phase velocity curves by the "Hedgehog" method indicate that the North Sea region is characterised by a low velocity zone of S-wave velocity of 4.35-4.45km.s^{-1} between depths of approximately 85-200km, while Scandinavia has a low velocity zone reaching down to about 400km, which begins at depths of 140-240km if its S-wave velocity is 4.5km.s^{-1} and at depths of 190-290km if its S-wave velocity is 4.4km.s^{-1}. Significantly higher velocities are found for western as compared to eastern Scandinavia.

S28

TELESEISMIC DELAY TIMES FOR UNDERGROUND NUCLEAR EXPLOSIONS TO SEISMOGRAPH STATION IN BRITAIN

A.S. White and J.D. Fairhead, Department of Earth Sciences, University of Leeds

Analysis of teleseismic P-wave travel time residuals from American and Russian underground explosion test sites to fifteen stations in Britain has been made, using the Jeffreys-Bullen travel time tables. Observations of first arrivals were obtained from ISC bulletins and directly from seismograms for more recent events. For Russian explosions a least variance technique was used to minimise systematic errors due to inaccuracies in origin times and epicentre locations. The results of the analysis indicate that residuals for Low net stations in Scotland are predominantly more negative than Eskdalemuir station while stations in the south of England are slightly more positive. The residuals determined for Lownet, using the Russian explosion data, are sufficient to give an indication of their station correction terms.

5 Author Index

Reference numbers of papers of which abstracts are presented in the foregoing pages are appended to the author's names below. The session to which each paper has been allocated is indicated by the Roman numeral.

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