ing on a sphere. We developed this technique to help us analyze patterns of propagating rifts, a recently discovered plate tectonic process whereby new midocean ridges occasionally break through plates, growing gradually longer along strike, and leaving behind in their wakes diachronous patterns of magnetic anomaly and bathymetric offsets (pseudofaults) as well as failed rifts.

We are applying this forward modelling technique to the evolution of the northeast Pacific, from the Cretaceous quiet zone boundary to the present. Shortly after anomaly 8 time, about the time of breakup of the Farallon plate into the Cocos, Nazca and Juan de Fuca plates and intersection of the Pacific-Farallon spreading center with the North American plate, the Pacific-Farallon spreading center segment north of the dextral Sila transform fault began propagating south at about the spreading half-rate. The transform fault which joined the propagating and dying rifts was swept along with the propagating rift tip; eventually becoming the Blanco transform fault when the rift stopped propagating and the Pacific-Juan de Fuca relative rotation pole shifted, at about 4.5 mybp. The end of the Blanco fracture zone system is thus joined by a pseudofault to the end of the Sila fracture zone. By the propagating rift mechanism, the Sila transform fault offset of about 150 km at anomaly 8 time has been transferred to the present Blanco transform fault system about 900 km to the south. Pseudofaults are an additional type of boundary at which other tectonic boundaries can terminate.

T 43

CLOCKWISE ROTATIONS OF THE JUAN DE FUCA RIDGE AND GORDA RISE: A CASE STUDY

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Trends of magnetic anomalies adjacent to the Juan de Fuca Ridge and Gorda Rise record the trends of these ridge segments in time and suggest that they have rotated in response to a change in spreading direction since 10 mybp. For this study, the trends of individual positive anomalies have been systematically determined using a linear regression method. Anomalies on the Pacific Plate west of the Gorda Rise and on the Juan de Fuca Ridge have been used to establish the rotation histories of the Gorda Rise and Juan de Fuca Ridge, respectively.

Both ridges have rotated approxiamtely 20° clockwise. Several stages of rotation, during which rotation rates are constant, are evident in each case. Rotation rates range from 1.3 to 8.5°/my. Maximum rates of rotation occurred between 5.3 and 2.8 mybp. The rotation histories of these segments, though similar, are markedly different. The Juan de Fuca Ridge has had a more easterly trend by 5-12° at all times prior to 2.8 mybp, than has the Gorda Rise, and the most rapid phase of rotation began 1 m.y. later on the Gorda Rise (4.3 mybp) than on the Juan de Fuca Ridge. Since 2.8 mybp both ridge segments have had a stable trend 18° E of N.

Ridge rotation is accomplished by differential, asymmetric spreading along the ridge axis. Hence, different stages of rotation and observed differences in rotation histories between ridge segments may result simply from variations in patterns of asymmetric spreading. If, however, each phase of rotation represents a response to a change in plate motions, it follows that several such changes have occurred and that the motions of the Juan de Fuca and Gorda Plates with respect to the Pacific Plate were different before 2.8 mybp.

T 44

THE OCEANOGRAPHER TRANSFORM: MORPHOTECTONIC CHARACTER OF A RIDGE-TRANSFORM INTERSECTION

Oceanographer Transform Tectonic Research Team
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Seven ALVIN dives and 4 ANGUS lowerings in the median valley and on the bounding wall (transform side) of the Mid-Atlantic Ridge-Oceanographer Transform intersection provide new insight into the dynamic interaction of ridge crest constructional processes with transform related deformation. The morphotectonic setting of the study area consists of constructional submarine volcanic terrain that exhibits a range of structural lineations with the predominant alignments being N-S, E-W and NE-SW. The intersection area is characterized by a closed contour deep with water depths in excess of 4600 m. Sediments in this basin are undisturbed but the southern margin of the deep is characterized by steep scarps in variably consolidated sediment which demonstrate recent tectonism. Young volcanics in the axial region of the median valley occur in elongate fault-bounded blocks trending 020°. These volcanics and the locally derived talus are cut by faults with dominant trends of 020°, 100° and 060° that become more numerous as the transform axis is approached. The oblique western wall of the median valley reflects the integrated effects of numerous faults with dominant 040° to 060° trends. Relatively old, degraded fault scarps in volcanic rocks, some of which are cut be mafic dikes, and very young faults in variably consolidated sediments were observed on the steep lower part of this wall (3800-3500 m water depths). The exposure of ultramafic rocks on the rift-bounding slopes at depths above 3800 m has profound implications for constraining the thickness of oceanic crust in this tectonic setting. The distribution of rocks within this structural setting supports the notion that the oceanic crust proximal to transform faults is very thin.

T 45

THE GEOLOGY OF THE OCEANOGRAPHER TRANSFORM: SUBMERSIBLE AND DEEP-TOWED CAMERA INVESTIGATIONS

Oceanographer Transform Tectonic Research Team
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A total of 7 ALVIN dives and 4 ANGUS camera lowerings located along the transform valley of the Oceanographer Transform have provided high resolution data concerning the geologic and tectonic character of a slowly-slipping ridge-transform-ridge plate boundary. The in situ recovery of a diverse range of gabbroic and ultramafic rocks from degraded escarpments positioned high-up on the inward-facing transform valley walls, as well as from the rift valley wall proximal to the transform boundary, strongly suggests that the oceanic crust is very thin (apparently less than 1000 m) adjacent to the truncating transform. The 2000 m to 3000 m relief of the transform valley walls appears to be a function of the integraded "stair-step" effect of the large number of blocks that are bounded by inward facing faults. We infer the sense of displacement on these faults to be predominantly dip-slip and a product of the profound change in physical properties of the oceanic lithosphere as the transform interface is approached. Evidence for recent tectonic activity is exhibited by small-relief faults that expose semi-consolidated sediment, and is confined to a narrow zone only several hundred meters wide which flanks the axis of maximum depth along the transform valley floor. We interpret this narrow zone to represent the currently active principal transform displacement zone (PTDZ). The fault-bounded terrain of the transform valley is radically modified through time by the growth of wedge-shaped sediment fans that are fed by a variety of mass-wasting mechanisms (debris flows, sediment slumps, spalling of talus from rock faces) that very quickly begin to obscure and later to bury all but the most recent expressions of active tectonism.

T 46

JAN-MAYEN RIDGE OF THE NORWEGIAN SEA

Bård Johansen (University of Oslo, Norway)
P.L. Stoffa
P. Buhl (Both at Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y. 10964)

New 24-fold CDP seismic data and two-ship multichannel Expanding Spread and Constant Offset seismic data on the Jan-Mayen Ridge have been acquired, analyzed and the results combined with magnetic and gravity data. Previous studies have suggested that the Jan-Mayen Ridge is a microcontinent created by a westward shift in the spreading axis from the Norway Basin into the East Greenland continental margin. Our new data leads to a description of the geological and geophysical structures of the Jan-Mayen Ridge related to this event. When we combine magnetic data with MCS data the area covered by flat, opaque, acoustic basement is, in some places, accompanied with relatively high magnetic amplitudes which are not related to any visible structures. The gravity data generally reflect the topography. At 70°N, 8.5°W, a north-south oriented Expanding Spread profile (ESP) and a Constant Offset profile (COP) were acquired. The CDP data consist of nine east-west lines covering the Ridge from the Norway Basin to the Iceland Plateau, and from the Jan-Mayen Island in the north to the Iceland-Faeroe Ridge in the south. In the northern and eastern parts of the Ridge the sedimentary sequences below the Oligocene truncation horizon are dipping and conform with acoustic basement. In the west the sedimentary sequences are blockfaulted and form an escarpment bordering the Basin west of the Ridge. Further south the sediments on the Ridge are disturbed. South of the bathymetric depression at 68.5° N the eastern part is faulted, and the Ridge is divided into different ridges (as described in earlier papers). We will present an interpretation of the ESP and COP in the northern and southern extensions of the Jan-Mayen Ridge based on this new data set and earlier published data covering the Ridge.

T 47

NORTHWARD-PROPAGATING SUBDUCTION ALONG EASTERN LUZON, PHILIPPINE ISLANDS

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Newly-acquired and preexisting marine Common Depth Point (CDP) seismic data confirm that subduction of the Philippine Sea plate under the eastern margin of Luzon is occurring south of approximately 18°N along the East Luzon Trough. The sediments in the western portion of the East Luzon Trough are often deformed by folding and faulting, and the acoustic basement underlying the sediments can be traced dipping landward beneath the margin slope on several lines. The intensity of deformation increases to the south between 18°N and 16°N, suggesting that the locus of subduction is propagating northward along the East Luzon Trough. A zone of closely-spaced faults in the sediment section at approximately 15.25°N corresponds to a linear belt of shallow earthquake epicenters. This zone may represent the surface expression of an east-trending left-lateral transform fault between the Philippine Trench and the East Luzon Trough. The Luzon margin landward of the East Luzon Trough from 15.5°N to 19°N consists of a series of NNE-trending basement ridges and intervening sediment-filled troughs. These ridges have controlled the pattern of downslope sediment transport, and may be associated with previous episodes of subduction along the eastern Luzon margin.

T 48

INTRAPLATE SEISMICITY OF ANTARCTICA AND TECTONIC IMPLICATIONS

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E.A. Okal (Dept. of Geology & Geophysics, Yale University, New Haven, Conn. 06520)

We present a comprehensive study of the seismicity of the Antarctic plate for the period 1925-1980. The total seismic energy released during this period in the interior of the plate, $3.2 \cdot 10^{22}$ ergs, is compared to figures for the African plate, of similar kinematics and size, and to the neighboring Nazca plate. We conclude that Antarctic seismicity is comparable to that of other plates, thus refuting the claim that a surrounding ring of spreading ridges hampers transmission of tectonic stress and leaves the plate stress-free.

In the Southeast Pacific Basin, where most epicenters are concentrated, it is shown that the line of maximum age in the plate, which is the locus of previous positions of the Nazca[Farallon]-Pacific-Antarctic triple junction, is a line of preferential stress release, along with more conventional features, e.g. fracture zones.

In the Indian Ocean, we study an M_s=5.5 earthquake Northeast of Kerguelen: its depth (45 km), tensional mechanism and low stress suggest that it represents a magmatic process related to the nearby hotspot, and possibly involving a pipeline structure, such as the one proposed by Morgan [1978].

T 34

BEHAVIOR OF THE GRÜNEISEN PARAMETERS AND OF THE THERMAL CONDUCTIVITY THROUGH PHASE CHANGES

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Raymond Jeanloz (Department of Geological Sciences, Harvard University, Cambridge, Mass. 02138)

Theory and measurements demonstrate that anharmonic effects (e.g., Grüneisen parameter, thermal expansion, thermal resistivity) decrease with increasing density upon compression of solids. Continuum (Debye-Grüneisen type) models predict that anharmonic properties should also decrease across a phase transition with a density increase; however, experimental data on materials transforming to high pressure phases with an increase in coordination number contradict this prediction. We present results from a model based on interatomic potentials which correctly predicts the increase in anharmonicity for simple compounds transforming from 6-to 8-coordinated structures, and confirms the importance of interatomic spacing (rather than density) in determining changes in thermodynamic properties due to polymorphism. Preliminary calculations of the Grüneisen parameter and thermal conductivity as a function of pressure and across B1-B2 phase transitions agree satisfyingly with the available data for several alkali halides.

Example: Thermal Conductivity (κ)

	Pressure (GPa)	$\frac{\delta \ln\kappa}{\delta p}$ (GPa^{-1}) Cal.	Obs.
KCl (B1)	2	0.37%	0.37 (±0.1)%
KCl (B2)	2	0.28%	∿ 0.20%
NaCl (B1)	2	0.24%	∿ 0.35%

T 35

G. Zou, H. K. Mao, P. M. Bell, and D. Virgo (Geophysical Laboratory, 2801 Upton Street, N. W., Washington, D. C. 20008)

Both ^{57}Fe-Mössbauer and x-ray diffraction data indicate the occurrence of a second-order phase transition in wüstite that occurs over a wide pressure interval. This transition is similar to one known to occur at low temperature but of greater magnitude. The pressure at onset of the transition is approximately 50 kbar, but cannot be determined exactly. Under increasing pressure to the 250 kbar limit of these experiments, and thus with increasing structural distortion, the volume becomes smaller than the extrapolated value of cubic wüstite and becomes comparable with the value of a high-density phase observed in shock-wave experiments above 600 kbar (Jeanloz et al., 1979; note that the shock pressure is a function of temperature). The structure of the new phase determined in the present study, however, is a rhombohedral distortion of the B1 cubic phase and is not the high-pressure B2 phase postulated by Jeanloz et al. (1979) from shock-wave data.

Reference: Jeanloz, R., T. J. Ahrens, and M. Somerville, FeO: equation of state to 2000 GPa (2 Mbar) (abstract), Eos, 60, 387, 1979.

T 36

THE SYSTEM Mg-Fe-O STUDIED UNDER SHOCK COMPRESSION TO 200 GPa

M. S. Vassiliou, California Institute of Technology, Seismological Laboratory, Pasadena, CA 91125
Thomas J. Ahrens

New Hugoniot equation of state measurements are presented for single crystal MgO and polycrystalline (Mg,Fe)O, magnesiowüstite being a possible lower mantle phase in equilibrium with ferromagnesian perovskite. Our results so far do not convincingly suggest any phase transformations (such as that discovered recently in FeO) to be occurring under shock across the magnesiowüstite series. New data for MgO up to 200 GPa appear consistent with existing data below 120 GPa. Data up to 200 GPa for $Mg_{0.6}Fe_{0.4}O$ can be adequately fit by a single equation of state, consistent with ultrasonic data for this material. Existing data (Los Alamos group) for $(Mg_{0.1}Fe_{0.9})O$ up to 120 GPa, and one new datum at 175 GPa, also do not appear convincingly to suggest a transformation. The nature of the FeO change itself might be much more complex than was initially suspected, and must be reexamined. Simple structural changes such as B1-B2 seem unlikely.

T 37

CALCULATION OF Fe-Mg PARTITIONING BETWEEN MAGNESIOWÜSTITE AND PEROVSKITE AND IMPLICATIONS FOR LOWER MANTLE COMPOSITION

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Thomas J. Ahrens

We have calculated the theoretical partition coefficient,

$$K = (x_{Fe}^{pv}/x_{Mg}^{pv})(x_{Mg}^{mw}/x_{Fe}^{mw}),$$

for the exchange of iron and magnesium between magnesiowüstite (mw) and perovskite (pv):

$$FeO + MgSiO_3(pv) \rightleftarrows MgO + FeSiO_3(pv),$$

where x denotes mole fraction. We use third-order finite strain and available thermochemical and equation of state data for the four components, estimating standard entropy, S^o, and enthalpy, H^o, for the perovskites from the linear variation of these quantities with molar volume for iron and magnesium solid-solution end-members. We find S^o values of 56.2 and 85.6 J/mole/deg and H^o values of -1097.8 and -718.0 kJ/mole for $MgSiO_3$ (pv) and $FeSiO_3$ (pv) respectively. The calculated value of K at 1000°C lies in the range 0.01-0.10 for pressures between 20 and 45 GPa, in agreement with the experimental observation of Bell, Yagi, and Mao that iron is strongly concentrated in the magnesiowüstite phase (K^{expt} = 0.08 for the above P and T conditions). Using Stacey's mantle temperature profile, we find that K increases from 0.1 to 0.6 between 700 and 1200 km, indicating that the degree of iron concentration in the magnesiowüstite decreases with depth. Modelling the upper portion of the lower mantle as olivine or peridotite indicates that density, bulk modulus, and bulk velocity are changed by no more than about 0.2% by this partitioning.

T 38

THE (γ-ε-ℓ) TRIPLE POINT OF IRON AND THE EARTH'S INNER CORE

J.M. Brown (Department of Geophysics, Texas A&M University, College Station, TX 77843)

Discontinuities in elastic wave velocities along the Hugoniot of iron have been interpreted as resulting from phase transitions. A phase diagram for iron based on both shock wave and low pressure data suggests that the (γ-ε-ℓ) triple point for iron occurs at a pressure near that found at the Earth's inner-outer core boundary. While this may largely be coincidental, several points can be made concerning the core. The solid phase of iron under inner core conditions is likely to be ε rather than γ iron. Calculations sensitive to crystal structure should be cognizant of the possible differences. Further, the change in slope of the fusion curve at the triple point provides a mechanism to constrain the size of the inner core. For a range of isentropes, geotherms will intersect the fusion curve over a more restricted range of pressures beyond the triple point. This suggestion is tentative since the effect of compositional variations on the high pressure phase behavior of iron mixtures has not been determined.

T 39

EQUATION OF STATE OF PYRITE

Christopher T. Creaven, California Institute of Technology, Seismological Laboratory, Pasadena, CA 91125
Malcolm R. Somerville and Thomas J. Ahrens

We report the results of six shock compression experiments on single-crystal pyrite (FeS_2) in the pressure range 9-180 GPa to complement the data of Simakov (1974). Our results do not agree with those of Simakov, who proposed a phase transition at ∿30 GPa. Instead, our data suggest a phase change in the range 70-90 GPa. The zero-pressure volume change associated with the transition is ∿4.8%. We find a zero-pressure density for the high-pressure phase of about 5.48 g/cm^3 compared to 5.3 g/cm^3 derived by Ahrens from Simakov's data. This discrepancy is attributable to two points we believe to be in the low-pressure region which were included in the previous analysis as part of the high-pressure phase. The phase transition in pyrite may be of the B1-B2 type. We estimate values of 190 GPa and 4.9 for the bulk modulus, K, and its pressure derivative K' for the high-pressure phase and a K of 162 GPa and K' of 4.5 for the low-pressure phase. We also determine a Hugoniot elastic limit of 8.1 GPa. The high-pressure data for pyrite are useful, in conjunction with data on other iron sulfides, in constraining the possible sulfur content of the core.

Detailed Investigations of Problems in Marine Tectonics

Crystal HI
Monday PM
Roger L. Larson (U of Rhode Island), Presiding

T 40

OCEANIC SPREADING RATE, CRUSTAL THICKNESS AND MAGNETIC ANOMALIES

I. Reid (Dept. of Geology, Dalhousie University, Halifax, N.S., Canada B3H 3J5)
H.R. Jackson (Atlantic Geoscience Centre, Bedford Institute of Oceanography, Box 1006, Dartmouth, N.S., Canada B2Y 4A2)

Newly available data indicate a general inverse correlation between total oceanic crustal thickness and spreading rates. This becomes apparent when results from the areas of slow spreading are included. Crust formed at spreading rates around 5 mm yr^{-1} averages 2-3 km in thickness, compared with 7-9 km for spreading rates above 40 mm yr^{-1}. There appears to be an upper limit on total crustal thickness, which is reached throughout much of the Pacific. The correlation is explained by thermal structure, with greater geotherm elevation under fast spreading ridges causing a higher degree of partial melting and magma segregation. Thicker crust is associated with increased magnetic anomaly amplitude; this may be due to a thicker magnetized layer or to greater fractionation of the parent magma. Hot spots and magnetic H-zones are exceptions to the general pattern and one associated with thick crust. The magnetic amplitude/crustal thickness ratio of H-zones is not anomalous.

T 41

SHALLOW CRUSTAL LAYERS - EAST PACIFIC RISE

T.J. Herron
Stoffa, P.L.
Buhl, P. (All at: Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964)

Analysis of multichannel seismic data from the East Pacific Rise near the Orozco Fracture Zone (12°N-ROSE Project) have revealed a seismic reflection at about 0.55 sec or 1.1 km below the sea floor. The interval velocity in this layer below the sea floor is about 4 to 4.5 km/sec. The reflection can be detected at various locations on a 200 by 200 km intersecting network of seismic lines laid out over the Rise crest. Sonobuoy data suggest that the reflection may correspond to the top of Layer 3. Other seismic data from the crest of the Rise near the Siqueiros Fracture Zone have revealed a layer just below the sea floor about 350 to 450 meters thick with an interval velocity of about 3 km/sec which may correspond to Layer 2A of seismic refraction studies. This layer is underlain, at the Rise crest, by another layer approximately 1.4 km thick with an interval velocity of about 5.5 km per sec. The bottom of this deeper layer is defined by a reflection that may be related to a magma chamber under the Rise crest.

T 42

PROPAGATING RIFTS - THE MOTION PICTURE

R. N. Hey
D. S. Wilson (both at: Hawaii Institute of Geophysics, Univ. of Hawaii, Honolulu, HI 96822)

We have developed a computer graphic technique to make movies illustrating plate tectonic evolution. The movies show sequences of predicted seafloor isochron patterns for two-plate spread-

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1980 AGU FALL MEETING

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AGU FALL MEETING
Head for the Hills
San Francisco · Dec. 8-12

Section Luncheons

Geodesy	Tuesday, December 9 Casa de Cristal 1122 Post Street	12 noon
Hydrology	Wednesday, December 10 Casa de Cristal	11:50
Oceanography	Tuesday, December 9 Nikko Sukiyaki Van Ness and Pine	12:15
Seismology	Tuesday, December 9 '1906 Drinking Establishment' Holiday Inn Golden Gateway	11:30
Solar-Planetary Relationships	Wednesday, December 10 Nikko Sukiyaki	11:45

Space is limited—reserve early! All luncheons—$7.50.

See page 928.

Cover. The aurora, displayed in multiple bands and photographed near Fairbanks, Alaska, by Malcolm Lockwood. This is a reproduction of a color plate from *Majestic Lights—The Aurora in Science, History and the Arts,* by Robert H. Eather. This book is AGU's most recent release.