the location of ridges and trenches of one plate, we are able to find the approximate Euler pole for the absolute motion of that plate. Our poles agree with those of Minster and others (1974) within 29 degrees for the larger oceanic plates. A pole calculated for the Pacific Plate 65 M.Y.B.P. using the boundaries of Hilde and others (1976) is in remarkably good agreement with the pole found by Clague and Jarrard (1973) from the trend of the Emperor seamounts.

T 94

AN ALTERNATE MODEL FOR ABSOLUTE PLATE MOTIONS IN THE EARLY TERTIARY

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Absolute plate velocities are determined for the early Tertiary from relative plate motions and the assumption of no net torque. For this determination a reconstruction of the plate boundaries was used with a model of relative plate motions that included Antarctica split into East and West portions. In the scheme used to reconstruct relative plate motions, Antarctica is particularly important because it is the only link between the mainly oceanic plates (Pacific, Farallon and Kula) and the other plates. The resulting set of absolute plate motions has lower RMS plate velocities and slightly less polar motion than a previous determination for the early Tertiary in which Antarctica was treated as a single plate. The splitting of Antarctica leads to absolute plate velocities which are more compatible with the observation for the present of the separation of the plates into faster-moving oceanic plates and slower-moving continental plates.

T 95

PLATE TECTONICS IN THE ARCTIC SEA ICE: A COMPARISON WITH LITHOSPHERE TECTONICS

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Plate tectonics as a process is not restricted to the earth's lithosphere. Axial accretion by itself occurs in permafrost ice wedges and other tensional ice cracks, and has been modeled with paraffin. Complete plate tectonics occurs naturally in some lava lakes, and in polar pack ice under conditions of subfreezing air temperature. In this paper we examine "ice plate tectonics" and make comparisons with similar processes in the lithosphere and other systems. Frozen leads are the ice equivalent of rifted ocean basins. Unlike the latter, however, lead opening is highly episodic - high rates of 10^{-1} to 10 cm/sec (10^{8} to 10^{7} times the early rates of downward thickening) are followed by intervals of quiescence during which the newly formed open water freezes over. Various generations of rifting are recognized by shades of gray - the youngest ice is generally the darkest. Renewed rifting is generally restricted to the youngest - hence thinnest - ice formed during the previous episode. The new rift may form anywhere within this youngest ice, however, and often follows the margin of the previous lead. Axi-symmetric accretion is rare. Lithosphere motion is much steadier and proceeds only 1 to 10^{2} times the rate of plate thickening (averaged over the first 1-10 m.y.). Thus the accretion zone is relatively narrow. However, the instantaneous plate boundary may be free to jump around within an ~ 1 to 5 km wide accretion zone which can be likened to the "latest lead" of ice accretion. Successive episodes of ice accretion often replicate the locus of initial opening, as in ocean-floor spreading.

T 96

ARE AFRICAN-PLATE TOPOGRAPHY AND VULCANISM SIMPLY RELATED TO UNDERLYING MANTLE STRUCTURE?

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Most plates are in motion with respect to the mantle underlying them, but Africa has been suggested to have been at rest over the underlying mantle for about the past 25 million years. Evidence for this includes: ending of the Walvis Ridge hotspot track at Tristan not the MAR; concentration of active hotspots on the African plate; upsurge of vulcanism over much of the plate from 25 m.y. ago; persistence of vulcanism in the same place in some areas throughout this period; development of a distinctive basin and swell structure over the plate; paleomagnetic evidence of no relative motion between Africa and the spin-axis. Absence of relative motion between Africa and the mantle in the Neogene and Quaternary affords a possible explanation of: Neogene development of the East African Rift System and the Red Sea; anomalous general elevation of the continent, which by causing rapid erosion has led to rapid progradation of such deltas as the Niger and submarine canyon development, sliding and erosion on the continental rise with increased deposition at its foot.

We have analyzed the distribution of volcanic areas within the African Plate by the polygon method of Thiessen (1911) and found a pattern similar to the multimodal pattern produced in experiments modeling mantle convection under a stationary upper layer. We scaled the dimensions of the laboratory model to the earth by assuming cells extending to the 700 kilometer discontinuity. The resulting rising current separation distances are similar to those between African plate hotspots. These similarities can be interpreted as indicating that African hotspots lie above rising mantle plumes producing a convective pattern suggestive of little horizontal movement of the overlying lithospheric plate.

T 97

GEOLOGICAL AND GEOPHYSICAL PARAMETERS FOR MID-PLATE VOLCANISM

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Mid-plate Cenozoic volcanism is widespread in Africa, where it is associated with uplift and faulting, and is almost completely restricted to terrains mobilized within the last 1200 Ma. These terrains exhibit somewhat greater heat flow and thinner lithosphere than the older Precambrian cratons. There is also a clear time correlation between the pause at ca. 45 Ma in the African apparent polar wander path and the outbreak of volcanism at ca. 35 Ma. Geophysical modelling indicates that domal uplift, heat flow anomalies, and mid-plate volcanism can be adequately explained in terms of an interplay between three parameters: sublithospheric thermal anomalies, plate thickness, and plate velocity. Quantitative conductive models show that significant thinning of the lithosphere can be accomplished by deep strong thermal perturbations or by upward-migrating perturbations of lesser strength. The latter is consistent with configurations for the East African-Ethiopian lithothermal systems derived from geophysical and geochemical data.

T 98

TECTONIC ELEMENTS AND DEFORMATION OF THE EASTERN MEDITERRANEAN

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Differential vertical movements of several evolving basins in the eastern Mediterranean are governed partly by plate convergence and partly by crustal structures inferred from the gravity anomaly trends or from the seismic reflection profiles. Eratosthenes Seamount is an elevated part of a northeast-trending geanticline truncated along its eastern flank by a graben with similar trend. A buried ridge (horst?) west of Eratosthenes extends north from Egypt almost to the Cypriot Arc and separates the Levantine Basin from the deeper Herodotus Basin to the west. The crust of the Levantine Basin, and possibly the Herodotus Basin, may be the subsided northern margin of the African continent. Its offshore features and trends are similar to those of northern Egypt and the Levant. There is little evidence for sufficient subduction of the African plate beneath the Turkish plate to accommodate the convergence of the two plates implied by the relative movement along other plate boundaries in the region. It is concluded that plate convergence is taken up partially by underthrusting along the Cypriot arc, but primarily by regional deformation along zones of weakness within a wide band stretching eastward from the Herodotus Basin along the northern edge of the African and Arabian plates. Regional tectonics are thus intermediate between subduction at the Hellenic arc and large scale deformation associated with continental collision further east.

T 99

A TERTIARY? RADIAL DEFORMATION PATTERN IN THE SOUTHWESTERN CARIBBEAN

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Radial deformation patterns about San Andres Island in the southwestern Caribbean sea extend outward for a minimum of 350 km. San Andres Island is the emergent part of a coalescing group of seamounts that form a large roughly circular platform. No igneous rocks are exposed on San Andres Island but earlier surveys show that the Island and adjacent seamounts are magnetized, and thus, volcanic in origin. Indirect evidence suggests age limits of Late Cretaceous and Miocene for the basement rocks.

A large system of 182 sea-floor faults and lineaments constitutes the structures forming the radial pattern. Although the southern and western quadrants contain only a few lineaments, applying least square techniques to the strikes of the 118 radial structures yields a best fit center 10 km. east of San Andres Island at 12.6° N. 81.6° W. Structures further than 350 km. from this center have least squares centers of intersection that are widely scattered indicating a minimum diameter of 700 km. of the area of influence of the plume. Axial symmetry about a point dictates a circular plan for the causal mechanism. If the causal mechanism is a magmatic intrusion or mantle plume, simple application of the models of Koide and Bhattacharji (1975) yield a diameter of between 200 and 400 km.

Koide and Bhattacharji, J. Econ. Geol., 70, 781-799, 1975.

T 100

CHARACTERISTICS OF INTER-ARC SPREADING IN THE MARIANA TROUGH

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Although an extensional origin of many marginal basins is reasonably secure, the mode of extension and processes responsible remains controversial. Interpretation of a detailed survey and of other available data in the Mariana Trough suggest instead that important differences from the processes at accreting margins occur in this extensional environment. The Mariana Trough is a lunate-shaped basin except that it is open at the south end. Spreading is confined to the axial region of the basin by the pattern of sediment distribution and by age-depth relationship. Geologic control suggests spreading half-rates of near 0 at the north end to over 4 cm/yr in the central section. Along its entire length, the spreading region is marked by high relief, but there is no consistent axial rift and no change of morphologic character with increasing spreading rate. A rough closure of the Mariana Trough can be made by a clockwise rotation of the frontal arc around a pole near 21°N, 138°E, T 87

ELECTRICAL PROPERTIES OF ROCKS DURING FRICTIONAL SLIDING

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H.F. Morrison (Dept. of Material Science and Engineering)

Two kinds of electrical phenomena are found to associate with rocks during frictional sliding: One is the changes in the electrical resistivity of saturated rocks; the other is a transient electrical potential occurring at the moment of slip. For saturated rocks, the change in the electrical resistivity during frictional sliding is determined by the availability of water from the surrounding environment. In undrained experiments where water is not available from the surrounding, both the premonitary and the coseismic changes are found to occur in the opposite directions of those in drained experiments where water is available from the surrounding. Models on the changes of the microscopic structures of rock during frictional sliding are constructed to interpret the observed changes in the electrical resistivity. For dry rocks, the electrical resistivity does not appear to change with sliding. A transient potential, however, occurs between the sliding blocks at the instant of slip. We tentatively interpret this transient electrical potential as due to a generation of electrical charges of opposite signs on the two sides of the sliding surface when they open at the instant of slip. The electrical charges neutralize each other through discharge when the two sides of the sliding surface come together and slip stops. This mechanism may be responsible for some observed earthquake lights.

T 88

THE EFFECT OF STRESS ON REMANENT MAGNETIZATION DURING CYCLIC LOADING

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A series of laboratory experiments have been carried out to examine the relation between stress, volumetric strain, and remanent magnetization (TRM and NRM). The tests were conducted inside a beryllium copper pressure vessel encased in a μ-metal shield at confining pressures to 1200 bars. The changes in remanent magnetization were observed with two flux-gate magnetometers. The sample was loaded in 200 bar increments to approximately 95% of its fracture stress and then stepwise unloaded. Each experiment consisted of multiple loading cycles.

During the first cycle, initial loading produced an increase in magnetic intensity of up to 20%. A decrease in intensity then occurred as stress was augmented to the peak stress. In subsequent cycles, as the rock was stressed to a value near the onset of dilatancy, the magnetization increased by up to 5% and leveled off. Further loading triggered dilatancy and a decrease in magnetic intensity. The volumetric strain and the magnetic intensity exhibited hysteresis. The magnitude of the hysteresis decreased with increasing cycle number. The permanent demagnetization of the sample and the increase in crack porosity also decreased with increasing cycle number.

The angle between the magnetic vector and the axis of greatest compression also exhibited a consistent behavior. During the first 20 to 30 percent of the stress cycle the magnetic vector rotated 5 to 15° toward the greatest compressional stress axis. Continued augmentation of the stress resulted in a rotation away from the stress axis.

These experiments suggest that there is a correlation between changes in crack porosity and changes in remanent magnetization during stress cycling.

T 89

DEPTH CALCULATION OF PIEZOMAGNETIC STRESS EFFECT FOR EARTHQUAKE PREDICTION

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Interpretation of piezomagnetic field changes in terms of focal-zone stress buildup requires modelling of the stress response of magnetic properties in the lithosphere. Calculations have been made to estimate the piezomagnetic effect as a function of depth, by considering the stress sensitivity of multidomain magnetite (Fe_3O_4). The responsiveness of magnetization to directed seismotectonic stress is gauged by an appropriate balancing of magnetocrystalline anisotropy energy,

$$\Delta E_K = K_1(\alpha_1^2\alpha_2^2 + \alpha_2^2\alpha_3^2 + \alpha_3^2\alpha_1^2) + K_2(\alpha_1^2\alpha_2^2\alpha_3^2)$$

and magnetoelastic anisotropy energy,

$$\Delta E_{\lambda\sigma} = -\tfrac{3}{2}\lambda_{100}\sigma \cdot f(\alpha,\gamma) - 3\lambda_{111}\sigma \cdot f(\alpha,\gamma).$$

The determining factor is taken as the character of the potential energy barrier between adjacent "easy" axes of magnetization in the multidomain crystal, and its variation with depth as the K's and λ's vary with temperature and hydrostatic pressure. The calculations indicate that magnetite becomes progressively more responsive to stress as depth increases. The Table shows the normalized stress sensitivity, i.e. the directed stress required to give an equivalent piezomagnetic effect, for regions of typical low and high geothermal gradients.

		low dT/dz("shield")		high dT/dz(ocean)	
Depth (km)	p (kb)	T(°C)	"stress"	T(°C)	"stress"
0	0	10	1.00	10	1.00
5	1.5	62	.71	108	.60
10	3	115	.49	202	.42
15	4.5	170	.37	296	.31
30	9	330	.18	538	.20
33				T_c=594	--
50	15	520	.13		
60	18	T_c=609	--		

The net effect is that the upper 15 km of the lithosphere is likely to be the most important in yielding observable piezomagnetic field effects, and such shallow-focus earthquakes are expected to be best to monitor geopiezomagnetism.

Plate Tectonics: Kinematic and Descriptive

North Cotillion, Wednesday 1330h
***D. E. Karig*, (Cornell University) and *D. M. Jurdy* (Princeton University), Presiding**

T 90

POSITIONS OF SOUTHERN CONTINENTS REVISED

E. J. Barron
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Because of the lack of unequivocal geophysical and geologic data to constrain the paleopositions of the southern continents, a variety of different reconstructions have been proposed. We propose a new reconstruction based on data from three critical areas: 1) The Falkland Plateau is included in the fit of South America and Africa presented by Bullard and others. Consequently, the Antarctic peninsula (Graham Land) lies along the western side of South America, adjoining the Andean province. 2) Madagascar is placed to the east of Mozambique (the southerly position) because of geophysical data from the Mozambique channel and the incompatible nature of Mesozoic history off the coast of Kenya for placing it in the northerly position. 3) The fit of Australia and Antarctica is specified by marine magnetic anomalies. However, the nature of anomalies off the west coast of Australia requires that the hypothesized seaway, Sinus Australis, did not exist between India and Australia in the Jurassic. Since present data suggest the gap probably was not filled by Tibet or Southeast Asia, this information with the addition of other geologic and geophysical data constrains the fit of India with Australia, Antarctica and Madagascar. The new fit assumes some crustal shortening during the formation of the Himalayas. The Seychelles, the Lord Howe Rise and other plateaus which may be continental fragments are included in the reconstruction.

T 91

SPECULATIONS ON THE ORIGIN OF MOUNTAIN BELTS, SPREADING CENTERS AND THE LOST CONTINENT OF PACIFICA.

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Zvi Ben Avraham (Israel Oceanographic Research and the Weizmann Inst., Israel)

By analogy with present day configurations of continental collision, we advance the hypothesis that all wide mountain belts involve massive continental collisions. This leads to the speculation that a large continental mass existed once in what is todays Pacific Ocean. This mass - which we call the Pacifica continent - could well have been part of the Pangea Super Continent. The breakup of this continent into fragments and their drift resulted in continental collision in South America, North America, Alaska, Kamchatka, Japan and East Asia. Furthermore, the submerged platforms in the Pacific Ocean such as the Ontong Java area, the Shatsky rise, and the Minihiki plateau may also be explained as remnants of Pacifica. The thick crusts of these plateaus, up to 40 kilometers and more, are thus predicted to be continental crusts. We suggest that Pacifica disaggregated in a manner similar to the breakup of Africa, producing continental slivers which may appear in the collision zone as 'island arcs'. Second, that all spreading centers on earth may have originated underneath continental masses. As proposed by Schuiling (1969), continental crust may act as a thermal blanket causing the warming up of the lower lithosphere and upper asthenosphere due to insulation and radioactive heat production. Combining the notion that spreading is initiated under continents with the idea that subducted ridges are responsible for back arc rifting and spreading, we find that the typical trench-continent-ridge consumption sequence causes volcanism, uplifted blocks, metamorphism and rifting in the orogenic collision belts. In cases of multiple collisions, with several continental slivers and ridges, the resulting geological record may contain several consecutive sequences juxtaposed on one another.

T 92

EVOLUTION OF THE INDIAN OCEAN

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Recent fracture zone and magnetic data have substantially added to our knowledge of the evolution of the Indian Ocean. It has been shown that Africa and Antarctica have been separating along a nearly north-south azimuth since the late Cretaceous. Early Tertiary anomalies in the Madagascar and Crozet Basins constrain the motion of India relative to Africa and Antarctica. These and other published data are interpreted using rigid plate tectonics to develop a model for the evolution of the Indian Ocean which eliminates some inconsistencies in earlier models. By extrapolating backwards in time from the late Cretaceous we also suggest a model for the breakup of Gondwanaland.

T 93

ESTIMATING ABSOLUTE EULER POLES FOR INDIVIDUAL PLATES

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A difficulty that arises in attempting to reconstruct plate motions during the early Tertiary and Mesozoic is that although some individual plate boundaries are known quite accurately, the global pattern of boundaries is not. Therefore we have examined the question of how accurately the absolute velocity of an individual plate can be determined in the absence of information about the motion of adjacent plates. Using geometrical factors (Forsythe and Uyeda, 1973) that depend only on

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