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B. 105. ordentliche Generalversammlung

Administrative Sitzung

13. Oktober 1989

Es sind 23 Personen anwesend.

1. *Vorlage des Jahresberichtes*

Der Vorstand hat im Berichtsjahr dreimal getagt. D. Bernoulli hat von A. Matter das Amt des Präsidenten übernommen und würdigt die von seinem Vorgänger geleistete Arbeit. A. Strasser wird als Vizepräsident bestimmt.

An der diesjährigen Versammlung wurde im Rahmen des Hauptthemas über Geologie/Geophysik und Dritte Welt gesprochen und ein internationales Symposium über Mantelstruktur veranstaltet. Obwohl solche Symposien der Weiterbildung dienen, war die Besucherzahl leider gering.

Die geplante Exkursion «Flyschs valaisans» musste wegen Schnee abgesagt werden.

Die Jahresversammlung 1990 wird vom 4.–7. Oktober in Genf stattfinden und Themen zum 50. Todestag von Emile Argand und zur Geologie des Alpenvorlandes umfassen. 1991 sind Tagungen zusammen mit dem Tektonikertreffen und über die Tiefenstruktur der Schweiz (NFP-20) geplant.

Die Tagung über die Tiefenstruktur der Alpen in Paris (Dez. 1988) wurde von 200 Teilnehmern besucht. Die Ergebnisse werden in einem Band zusammengefasst, der für Mitglieder etwa 50 Franken kosten wird. Die Abrechnung erfolgt getrennt vom Budget der SGG.

Die Gestaltung der zukünftigen Jahresversammlungen wird diskutiert. Symposien haben eine grosse Attraktivität und können in den Eclogae publiziert werden, lassen aber weniger Raum für freie Themen. Es soll deshalb in Zukunft jeweils nur ein Symposium abgehalten werden, und vor allem junge Geologen sollen zur Teilnahme ermutigt werden (Votum R. Trümpy). Auch soll vermieden werden, dass thematische Symposien unterbrochen werden oder Sitzungen am Samstagnachmittag stattfinden, selbst wenn dies Überschneidungen mit dem Hauptprogramm zur Folge hat (Voten R. Plancherel, M. Fischer, P. Heitzmann). Ferner müssen in Zukunft die Programme früher publiziert werden, um eine genügend lange Frist für die Ausarbeitung von Vorträgen und Posters und für die Anmeldung zu ermöglichen (Voten B. Loup, J.P. Berger).

2. *Bericht des Redaktors*

H. Funk verliest den Bericht von A. Lambert, der noch den Band 81 (1988) der Eclogae gestaltet hat. Auf 934 Seiten wurden 44 Artikel publiziert, davon 17 auf deutsch, 12 auf französisch und 15 auf englisch. Der Dank richtet sich an die Autoren und die Reviewer sowie an den Birkhäuser Verlag. D. Bernoulli dankt seinerseits H. Funk für die Übernahme der zeitraubenden Redaktionsarbeit.

3. *Vorlage der Jahresrechnung*

Die Betriebsrechnung 1988 wird an die Anwesenden verteilt. Die Bilanz für 1988 ist ausgeglichen.

4. Die *Rechnungsrevisoren* empfehlen die Annahme der Abrechnung.

5. Der *Vorstand* wird für das abgelaufene Geschäftsjahr einstimmig *entlastet.*

6. *Vorlage des Budgets*
Für 1990 werden die Autorenbeiträge höher veranschlagt; es wird an die Autoren appelliert, mehr Beiträge zu leisten. Dennoch muss mit einem Verlust von Fr. 21 000.– gerechnet werden. Es wird deshalb unumgänglich, an der nächsten Generalversammlung eine Erhöhung der Mitgliederbeiträge für 1991 zu beantragen.

7. Der *Jahresbeitrag* für 1990 bleibt unverändert.

8. *Wahlen in den Vorstand*
Als neuer Sekretär wird M. Burkhard (Neuchâtel) vorgeschlagen und einstimmig gewählt. A. Parriaux und P. Homewood treten auf nächstes Jahr zurück. Es werden deshalb zwei neue Beisitzer gesucht; mögliche Kandidaten sollen vorgeschlagen werden.

9. *Wahl eines Rechnungsrevisors*
M. Septfontaine tritt zurück. W. Winkler hat sich als Nachfolger anerboten und wird gewählt.

10. *Antrag von L. Jemelin*
L. Jemelin schlägt vor, dass aktuelle Themen der Schweizer Geologie (z.B. Tunnelbauten, NFP-20) an den Versammlungen vorgestellt werden sollten. Der Vorstand wird je nach Bedürfnis Beiträge auswählen.

11. *Verschiedenes*
Die SGG wurde aufgefordert, Wahlvorschläge für Vertreter in der Geologischen Kommission einzureichen. P. Haldimann hat sich als Kandidat zur Verfügung gestellt. Damit ist die direkte Verbindung zum Vorstand gewährleistet. Ebenso ist durch ihn die Quartärgeologie vertreten.

P. Heitzmann erwähnt, dass das Programm der SANW durch die Fachgesellschaften verschickt wird und dass man als Mitglied verschiedener Fachgesellschaften mehrere Exemplare erhält. Dieses Problem kann aber vorläufig nicht gelöst werden. Auch wäre ein erdwissenschaftliches Informationsbulletin erwünscht. Das INFO soll umstrukturiert werden, und der Informationsfluss soll durch Korrespondenten an den verschiedenen Instituten sichergestellt werden.

Die Sitzung wird mit einem Aperitif beendet. Der Sekretär: A. STRASSER

Wissenschaftliche Sitzung

12. Oktober 1989: Fachsymposium «Mantelstruktur und Geotektonik». Gemeinsam mit der Schweizerischen Mineralogisch-Petrographischen Gesellschaft und der Schweizerischen Gesellschaft für Geophysik. (Vgl. S. 208–216).

13. Oktober 1989: Fachsitzung «Geologie/Geophysik und Dritte Welt». Gemeinsam mit der Schweizerischen Gesellschaft für Geophysik.

14. Oktober 1989: Fachsitzung «Geologie/Geophysik und Dritte Welt». Präsentation allgemeiner Themen.

Mantle structure and Geotectonics

Organized by the Swiss Geophysical Society,
the Swiss Geological Society
the Swiss Mineralogical and Petrographical Society

Abstracts of the Symposium held at the Annual Meeting of the Swiss Academy of Sciences 1989 in Fribourg

Petrology of the earth's mantle

By A.B. Thompson

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Recent advances in high-pressure experimental petrology permit quite detailed understanding of the nature and P–T locations of upper mantle mineral transitions. Likewise, thermochemical and acoustic velocity measurements on appropriate high P–T minerals enables close correlations with seismic observations.

There is conflicting data on the SiO_2 content of the mantle relative to olivine and pyroxene components, or their high-pressure equivalents. This considerably influences the interpretation of the differences in mineralogy between sub-contintental and sub-oceanic lithosphere, to depths of at least 400 km; the relative composition and density of subducted slabs, compared to adjacent mantle; and, consequently, models of mantle convection and the depths to which subduction can occur.

Despite the ubiquity of olivine in mantle xenoliths sampled by rising magma from the upper 200 km of the mantle, cosmic element-abundance data favours greater pyroxene (and therefore garnet) stoichiometry for the mantle as a whole.

Phase transitions in the olivine component (to spinel phases) can be well correlated with the 440 km seismic discontinuity. Correlation of the 670 km discontinuity with transitions mainly in the pyroxene-garnet component (to ilmenite, perovskite phases; or spinel, or MgO-FeO, with stishovite) is uncertain, largely because of lack of direct knowledge about actual temperature distribution, and the effect of minor components on mineral stability.

A chemical discontinuity at 670 km is consistent with aspects of seismic data, the apparent behaviour of subducted slabs, and with cosmic element-abundances. Subducted slabs may transport pyroxene-garnet component through an olivine enriched (basalt depleted) uppermost mantle, down to 670 km.

Seismic data for the lower mantle appear to correlate with pyroxene stoichiometry, enriched in FeO compared to the upper mantle. A chemical boundary at 670 km, with the expected density contrast in pyroxene component, would inhibit slab penetration into the lower mantle.

The influence of phase transitions and chemical heterogeneity on mantle convection

By U. CHRISTENSEN

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Numerical model calculations are used to shed light on the influence of phase transitions and chemical variations on the most prominent expressions of global mantle circulation: sinking slabs of subducted oceanic lithosphere and hot plumes rising presumably from the D^{II}-layer above the core-mantle boundary. In a model series the ability of slabs to penetrate the seismic 670 km-discontinuity is studied. If the discontinuity represents a pure phase change to the perovskite structure, it is unlikely to stop the slab. It may do so if 2–4% chemically induced density variation are superimposed. However, there is little evidence for the 100 to 200 km depression of the boundary in subduction regions, which would be expected in this case, and whole mantle convection is the favoured model.

The basaltic oceanic crust transforms to eclogite upon subduction and becomes denser than the mantle peridotite. Numerical calculations suggest that it may segregate in the D^{II}-layer and form "anti-continents" at the core-mantle boundary. Part of the former oceanic crust can later become entrained into hot rising plumes and affect the geochemical signature of hot-spot basalts. A newborne plume is shown to consists of a large thermal diapir of hot rock, followed by a thin pipe of fast uprising flow. The head of the plume, when it reaches the bottom of the lithosphere, may give rise to large magmatic events like the continental flood basalts. The trailing pipe will persist after the head of the plume has dispersed and produce moderate amounts of melt, giving rise to a hot-spot track.

The role of mantle instabilities in the tectonics of mountain belts

By P. ENGLAND

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The India-Asia collision zone is the largest active example of a zone of continental collision; part of this zone – the Tibetan plateau – is the largest active region of continental extension. Throughout most of the Tertiary, the tectonics of the Tibetan plateau were dominated by north-south shortening, a significant proportion of which took place on east-west striking thrust faults. For the last 5 m.y. or so the plateau has been thinning by the mechanism of extension on north-south trending normal faults. One explanation for abrupt change in tectonic style in the Tibetan plateau comes from considering the termal evolution of thickened continental lithosphere. The lower part of the lithosphere consists of a thermal boundary layer which, when thickened by horizontal shortening, is colder and denser than its surroundings. Convective instability of the thickened thermal boundary layer and its replacement by hot asthenosphere would raise rapidly the surface elevation and gravitational potential energy of the overlying part of the lithosphere. Numerical experiments show that, for a range of lithospheric parameters, the increase in surface height (as much as 2 km) and of potential energy (5 to 10×10^{12} J m^{-2}) resulting from convective instability of the lower lithosphere are sufficient for east-west extension to replace north-south compression as the dominant feature of the stress field of the Tibetan plateau. This mechanism is not restricted to the Tibetan plateau; there is evidence to suggest that thermal instability of the lower lithosphere may also have lead to the start of extension in the Basin and Range province and in the Betic Cordillera. The implications of convective thinning of the lithosphere for the metamorphic and magmatic evolution of continental collision belts will be discussed.

The mantle structure in Central Europe and the Mediterranean inferred from seismic tomography

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Delay time tomography is an inversion method for investigating the three-dimensional seismic velocity structure of the earth. The data – delay times – are derived from travel times of seismic waves; in most cases P-waves. Using travel time data from many earthquake-station combinations offers the possibility to estimate the amplitudes of the three-dimensional seismic velocity field by inversion of the travel time data. An important step in this procedure is the quantification of the way on which seismic waves illuminate the earth's interior. It is assumed that the earth's velocity heterogeneity can be described as a small deviation (few percent) from a radial (one-dimensional) model of seismic velocity. It is advantageous to use this radial model as a reference in tomography. This allows the conversion of the nonlinear relation between travel time and seismic velocity into a linear relation between delay times (the difference between the travel time and the model prediction) and lateral velocity heterogeneity. Furthermore the illumination of the Earth by seismic waves can be computed from the reference model as an approximation of the actual ray geometry. The accuracy of this approach depends heavily on how well the adopted reference model represents the actual laterally averaged Earth structure.

The largest data base available for delay time tomography has been collected by the ISC. Since the early sixties the ISC has routinely located earthquakes using the Jeffreys-Bullen travel time tables of P-waves. Output of the location procedure are dependent sets of earthquake hypocenter parameters and of travel time delays. The number of data and unknowns in delay time tomography can be very large. In large scale tomographic problems, typically O (10^6) delay time data are inverted for estimates of O (10^4–10^5) unknowns. The unknowns represent the three-dimensional velocity heterogeneity but also account for the effects of earthquake mislocation and possible station bias.

For the European-Mediterranean region several tomographic results for the P-velocity heterogeneity have been obtained recently using different ISC data sets and different reference models: (i) the upper mantle heterogeneity derived from primarily regional data using the Jeffreys-Bullen model as a reference, (ii) the upper and partly the lower mantle (down to 1'400 km) heterogeneity using both regional and teleseismic data and using the Jeffreys-Bullen model as reference and, (iii) using a newly derived reference velocity model.

The velocity heterogeneity in the crust and lithosphere in the regions studied often exhibits a close correlation with larger scale geological structures at the surface and in some regions, e.g. the Tyrrhenean and Aegean regions, slab subduction can be identified. For most of the studied Earth volume, however, the interpretation of the imaged anomalies in terms of geodynamic processes is very difficult.

The power of large scale delay time tomography is to reveal the three-dimensional structure of the earth. However, the results suffer from many uncertainties related to the data, method and the assumptions involved, which make it very difficult to interpret the results obtained. For instance, the linearity between delay times and velocity heterogeneity is not always warranted, the usefulness of delay time data for tomographic mapping is at least questionable, and it is difficult to obtain reliable and interpretable accuracy and resolution estimates.

Tomographic Image of the Pacific Slab under Alaska

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Between January 1972 and December 1988 the U.S. Geological Survey recorded some 15'000 earthquakes in an area of roughly 500 km radius around Anchorage at 200 temporary and permanent seismic stations. Filtering this original data for all earthquakes that were recorded by at least 10 seismic stations (counting P-wave arrivals only) and that could be located with a maximum gap of 120 degrees resulted in a data set of 110'000 observations belonging to 5'000 events. This data set of local earthquakes has been inverted to obtain a tomographic image of the three-dimensional velocity structure down to a depth of 200 km.

The area between Kodiak Island in the south and the Denali Range to the north is characterized by high-seismic activity due to the subduction of the Pacific plate under the continental lithosphere of the Alaskan Peninsula. To image this large area with a block size of $10 \times 10 \times 10$ km only an approximative solution to the full inversion could be calculated. Tests with artificial data sets are used to check the reliability of the solution.

The dominant features in the tomographic image are elongated deep reaching velocity anomalies striking SW-NE parallel to the Cook Inlet. Surprisingly, the largest continuous anomaly is a region of low P-wave velocity. This anomaly parallels and overlies the zone of relatively high P-velocity associated with the descending colder slab. Profiles perpendicular and oblique to the strike of these anomalies show the subduction to be oblique, i.e. the maximum dip of the slab is not perpendicular to the strike of the anomalies associated with the subduction. The maximum amplitudes of the P-velocity anomalies are $+7\%$ for the slab and -10% to -15% for the areas of low velocity. In the southern part of Seward Island where the slab is well developed the earthquakes are concentrated in the crust and along a zone that includes the uppermost part of the slab and the region between the high and the low P-velocity anomalies. Further to the north where the amplitude and the size of the high-velocity slab are decreasing the seismogenic zone spreads away from the slab into the continental lithosphere.

Pacific/Anti-Pacific bipolarity in mantle structure and dynamics

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Large-scale regularities in the orientations of maximum horizontal crustal shortening (MHS), as derived from kinematic analysis of Cenozoic deformation within the Mediterranean and Circum-Pacific orogenic belts, led to the concept that these belts represent the zone of lithospheric convergence and shearing between two major, expanding geotectonic units, in antipodal position, the Pacific unit and the Gondwana unit.

In the Pacific hemisphere, which is centered at 170 W/0 N (pole P), Mesozoic and Cenozoic diverging movements of plates away from the central Pacific region toward the margins of the Pacific are documented by the breakup of the paleo-Pacific lithosphere. With respect to the Pacific plate the Izanagi and Kula plates moved toward the northwest and were subducted under Asia and Alaska, the Farallon plate moved toward the northeast and was subducted under North America and South America, and the Phoenix plate moved toward the southeast and was subducted under South America and Antarctica. During the same period the Pacific plate, formed near the Phoenix-Farrallon-Izanagi triple junction about 190 m.y. ago, was growing from a small plate to its present large size. Notably, the site of origin of the early Pacific plate was located near the "center" of the present Pacific plate, at pole P. In addition to the large-scale diverging plate movements, as derived from seafloor spreading, large-scale tectonic transport is also documented by the accreted terranes of the circum-Pacific orogenic belt. In the anti-Pacific hemisphere, which is centered in Africa at 10 E/ 0 N (pole A), diverging movements of plates away from Africa are demonstrated by the breakup of Gondwana.

Pole P is the pole of a spherical zone containing the epicenters of the Juan de Fuca Ridge, the Gorda Ridge, the East Pacific Rise and the Pacific-Antarctic Ridge. Pole A is the pole of a spherical zone containing the epicenters of the Carlsberg Ridge, the Southwest branch of the Indian Ocean Ridge and the Mid-Atlantic Ridge up to Gibbs fracture zone. The poles coincide with the "centers" of the Pacific and African plates.

In order to explain the large-scale diverging movements of lithospheric plates in the Pacific and anti-Pacific hemispheres, a bicellular convection system in the mantle, consisting of two toruslike convection cells, has been proposed, with ascending flow under the central Pacific and African plates, and converging and descending flow at 70 to 90 degrees distance from both pole P and pole A. The bicellular convection governs the large-scale trends and patterns of lithospheric evolution. Whereas the oceanic lithosphere is directly taking part in the circulation of mantle material, the continental lithosphere mainly remains at the surface of the earth (origin of geotectonic cycles).

Recent geophysical and geodetic investigations show that the same, fundamental Pacific/anti-Pacific bipolarity is evident in the degree 2 distribution of lateral heterogeneities of seismic velocity and density in the lower mantle, as well as in the residual geoid. This points to a common origin of the anomalies and the bipolarity. Reduced seismic velocities, indicating less dense and relatively hot material, observed in the lower mantle beneath the central Pacific plate and beneath the African plate, are in good agreement with the mantlewide bicellular convection proposed on geotectonic considerations.

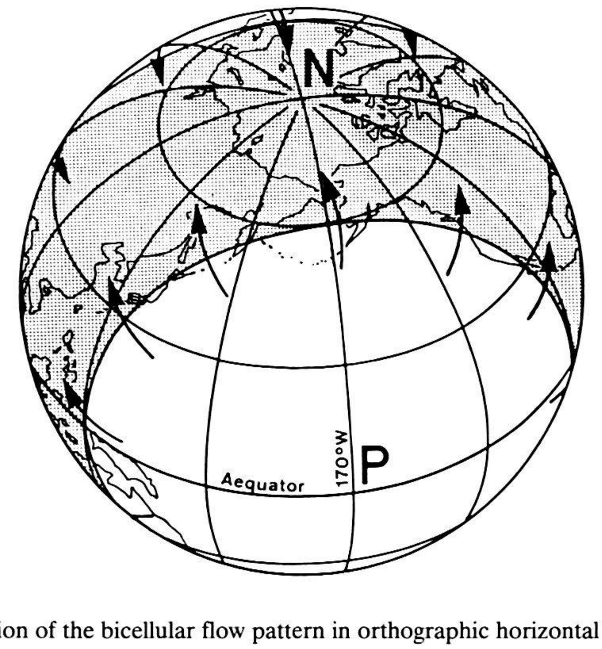

Fig. 1. Idealized representation of the bicellular flow pattern in orthographic horizontal projection. P: Pacific pole at 170 W/0 N. Light areas: Diverging lithosphere. Shaded areas: Zone of converging lithosphere.

Oceanic, terranes, fast instantaneous velocities and plate kinematics

By J.A. Tarduno

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Paleomagnetic analyses have become an essential part of the study of the tectonostratigraphic terranes which compose large portions of the Circum-Pacific margin. While considerable debate exists concerning the displacement of terranes having continental affinities, few geologists question the allochthonous nature of those having an oceanic character.

Most often velocity estimates derived from paleomagnetic studies are "averaged" values, obtained by dividing the total paleolatitude shift by the difference between magnetization and estimated accretion ages; they reflect net poleward transport over a long time interval and are *minimum* estimates because they reflect only the poleward component of motion. If a plot of paleolatitude versus time can be constructed for a given terrane, an "instantaneous" poleward velocity can be obtained providing an opportunity to measure the velocity of plates whose spreading history has been partially or completely lost due to subduction.

Data from Japan and California provide examples of these analyses. New paleomagnetic data from the Tokoro Terrane of Hokkaido, Japan, suggest an equatorial origin in Late Jurassic to mid-Cretaceous times. This paleolatitude determination combined with a known Campanian accretion age yields a minimum absolute velocity of 13 cm/yr, higher than any present-day plate velocity. New paleomagnetic data from the 101–89 Ma Laytonville Limestone of northern California confirm a southern hemisphere origin as first proposed by Alvarez et al. (1980). An "instantaneous" poleward velocity is recorded by the systematic inclination decrease of paleomagnetic specimens with respect to decreasing age within the section. Conservative estimates place this minimum velocity at 15 cm/yr, again higher than any present-day plate velocity.

The subduction of old oceanic crust at the boundaries of relatively small oceanic plates is hypothesized as the driving mechanism to explain the measured velocities. For the Tokoro Terrane, this geometry is represented by the Izanagi Plate while the Farallon and Phoenix Plates may accommodate the transport required by the Laytonville Limestone data. Interestingly, detailed plate reconstructions of these plates have independently predicted rapid motion. Similar plate geometries and resultant velocities have probably existed at other times in the past, but their detection may have been hindered by a low preservation potential.

Evolution of Laurussia: a study in Late Palaeozoic Plate Tectonics

By P.A. Ziegler

University of Basel

Late Cambrian to late Silurian convergence of Laurentia-Greenland and Fennoscandia-Baltica culminated in their suturing along the Arctic-North Atlantic Caledonides and thus the assembly of Laurussia. During the Devonian and Carboniferous Laurussia played the role of an independent lithospheric plate. Late Silurian consolidation of the Arctic-North Atlantic megasuture entailed a suture progradation into the domain of the Ural Ocean. By early Devonian time, the southern margin of Laurussia was marked by the Proto Tethys-Proto Atlantic subduction zone, its eastern margin by the Pacific arc-trench system and its northern margin by the Innuitian collision zone. Its eastern margin was passive and faced the Uralian back-arc ocean.

Gondwana-derived microcratons became accreted to the southern margin of Laurussia during the Caledonian and the middle Devonian Acado-Ligerian orogenic cycles. The Arctic craton became sutured to its northern margin during the Innuitian orogeny straddling the Devonian-Carboniferous boundary.

During the Devonian Laurussia remained almost stationary with the equator crossing the Hudson Bay, while Gondwana converged with it in a dextral-oblique, clockwise rotational mode. Initial contacts between the two megacontinents were established during the Famennian. From this time on, Laurussia began to rotate in unison with Gondwana in a clockwise mode. Carboniferous closure of the western Proto Tethys and the Proto Atlantic culminated in the late Carboniferous-early Permian suturing of Gondwana and Laurussia. Moreover, during the Late Carboniferous and Permian Kazakhstan and Siberia became accreted to the eastern margin of Laurussia. With this Laurussia lost its identity and became a major constituent of Pangea.

Consolidation of the Variscan-Appalachian megasuture and locking of its subduction system was accompanied by a suture progradation to the southern margin of Pangea. This entailed its late Permian and Triassic northward drift.

It is speculated that principal driving forces of plate motions are drag-forces excerted by the convecting asthenosphere on the lithosphere. Slab-pull and ridge-push are probably ancillary forces. Compressional stresses can be transmitted through the lithosphere over great distances. The Carboniferous drift patterns of Laurussia suggest that it became decoupled from the asthenosphere as a consequence of Gondwana colliding with its southern margin.

Mantle convection models must take into account the drift patterns of continental cratons. From Mid-Mesozoic times onward these are constrained by sea floor magnetic anomalies. Earlier reconstructions of the distribution of continents are mainly based on paleomagnetic, paleoclimatological, paleobiological and tectonic criteria.

Phanerozoic Plate Tectonic Reconstructions: Insights into the Driving Mechanism of Plate Tectonics

By C.R. Scotese

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Plate tectonic models describing the development of the Atlantic Ocean (Srivastava, Rowley and Cande), Indian Ocean (Patriat, Royer), and Pacific Ocean (Atwater, Engebretson, Sager) have been combined with preliminary plate tectonic models for Asia (Rowley), Tethys (Sengör, Dercourt et al.), the U.S.S.R (Zonenshain et al.), and the Paleozoic (Scotese) to produce a global model of Phanerozoic plate motions. 50 plate tectonic reconstructions will be presented, and a computer animation will be shown illustrating the movement of the continents and the development of the world's ocean basins since the late Precambrian.

The pattern of plate motion during the last 600 million years can be characterized as "episodic". Long intervals of steady-state plate motion (lasting 20–50 million years) have been interrupted at irregular intervals by tectonic "events" that have triggered global changes in the rates and directions of plate movement. At least 12 global events can recognized during the Phanerozoic. These events took place during the latest Precambrian, Llandeilo-Caradoc, Middle Devonian, mid-Carboniferous, Early Permian, Late Triassic, Middle Jurassic, Early Cretaceous (Valanginian), Cretaceous Quiet Zone, latest Cretaceous (Maestrichtian), middle Eocene, and early Miocene. In addition to these major events, numerous second-order events can be recognized.

It appears that these global plate reorganizations arise from interactions between the plates, and are not the result of deep-seated events in the asthenosphere. The loss of a subduction zone due to continent-continent collision, or the loss of a spreading center due to subduction of a ridge, are the two principal events that trigger global plate reorganizations. From the pattern of plate motion during the last 600 million years, it is clear that the forces that drive the plates are concentrated in the lithosphere (slab pull and ridge push), and that the pattern of convection in the Earth's interior plays little or no role in determining the movement of the plates.