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Plate Tectonic Evolution of the Southern Ocean

Kurzfassung

Neuere Rekonstruktionen zeigen, dass Afrika sich vor 155 Millionen Jahren von der Antarktis trennte, gefolgt von der Bildung ozeanischer Plateaus bis vor 80 Millionen Jahren. Die tektonische Entwicklung des südöstlichsten Pazifiks verursachte die Formation von Rückensystemen, die die Entstehung von Sedimentdriften unterstützten.

Abstract

Recent reconstructions show that Africa broke away from Antarctica at 155 million years ago. This was followed by the formation of oceanic plateaus until 80 million years ago. The tectonic evolution of the southeasternmost Pacific caused the formation of basement ridges, which supported the growth of sediment drifts.

Résumé

Des reconstitutions récentes montrent que l'Afrique s'est séparée de l'Antarctique il y a 155 millions d'années. En conséquence, il y a 80 millions d'années des plateaux océaniques s'étaient formés encore. L'évolution tectonique du Pacifique du sud-est causait la formation des arêtes qui favorisaient celle des sédiments dérivés.

Keywords

Geophysics, Plate Tectonic Reconstruction, Oceanic Gateways

1. Introduction

The evolution of the movement of continental and oceanic plates plays an important role nowadays in our understanding of the dynamics of ocean current systems and the associated long-term global climatic change. Movements of plates cause openings and closures of ocean basins and oceanic gateways and, therefore, affect the large-scale water circulation on our planet. For instance, the final opening of the seaway between South America and Antarctica 25–30 millions years ago caused the isolation of the Antarctic continent and the beginning of the southern hemisphere's glaciation.

2. Tools for Plate Reconstruction

Seafloor topography as well as large structures in the ocean crust can be identified and mapped by satellite altimetry, which aids enormously in the reconstruction of plate tectonic movements. The images show the extent of mid-ocean ridges, deep abyssal plains, seamounts, transform and fractures zones and the continental shelves. In particular the identification of fracture zones and mid-ocean ridge axes enables researcher to reconstruct flowlines along which the crustal growth from the seafloor spreading centers occurred.

Long before satellite altimetry came into existence, measurements of the magnetic field and its anomalies over the ocean basins have been the primary tool of plate reconstruction. Shipboard or airborne magnetic surveys measure the polarity reversals of the earth magnetic field, which is preserved in oceanic crust from the time when new crust was formed at spreading centers.

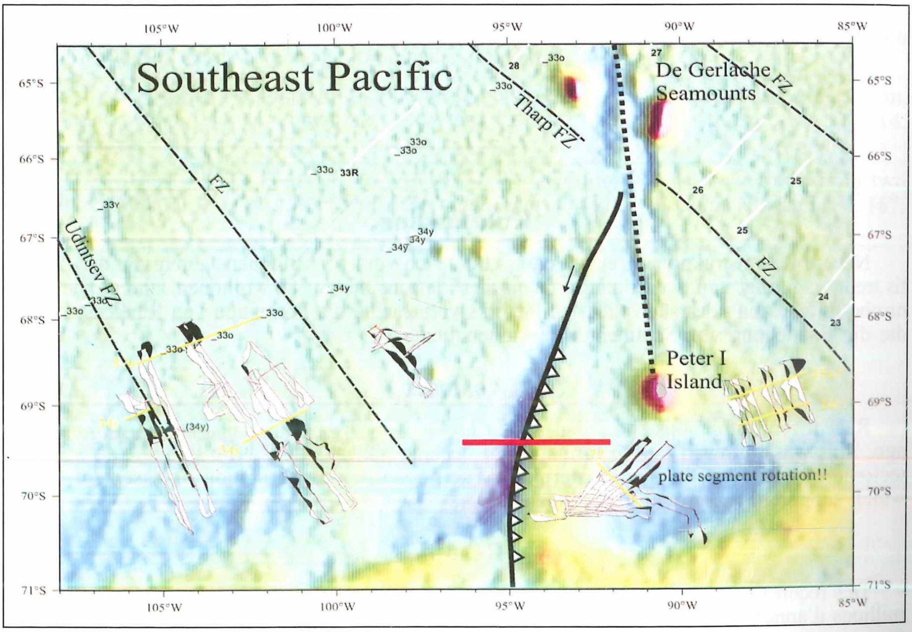

Fig. 1: Satellite-derived gravity anomaly map of the southeasternmost Pacific and Pacific-Antarctic margin showing tectonic features such as fracture zones (dashed lines) and basement ridges (dotted lines) and magnetic field reversal data from helicopter-magnetic surveys. The numbers indicate the magnetic reversal chrons (i.e. 34y = 84 million years ago; 25 = 59 million years ago). The red line marks the seismic profile AWI–94041, which is not depicted in this essay.

The combination of magnetic stripe pattern identification and delineation of fracture zones and spreading centers allows to model rotation poles (stage poles, finite poles, instantaneous poles) of crustal segments on a sphere and to compare with observed ones. While the methods above refer to past plate motions, geodetic measurement of fix-points on the earth surface using Global Positioning System (GPS) techniques allows to estimate the present relative motion between those fix-points of two or more different plates.

3. Key Areas of Interest

3.1. Southern Atlantic "Gateway"

Results from recent geophysical surveys in the South Atlantic, the Weddell Sea and the Scotia Sea have contributed to a better understanding of the reconstruction. So have recent extensive seismic surveys of the Agulhas Plateau (south of South Africa) shown that this plateau consists of overthickened oceanic crust evolved by extensive magmatism and volcanism 85–110 million years ago (during Late Cretaceous) after the Gondwana break-up in this region (GOHL & UENZELMANN-NEBEN 2001), while previous studies suggested a dominantly continental origin. The plateau evolved initially as one large plateau and was separated by a spreading axis into parts which now form the Agulhas Plateau, Maud Rise (Antarctica) and East Georgia Rise (Falkland Plateau).

Recent magnetic surveys flown by helicopter north of the Antarctic continental margin in the eastern Weddell Sea and the Rijser-Larsen Sea resulted in a new model for the break-up between Africa and Antarctica. The break-up began with two indepen-

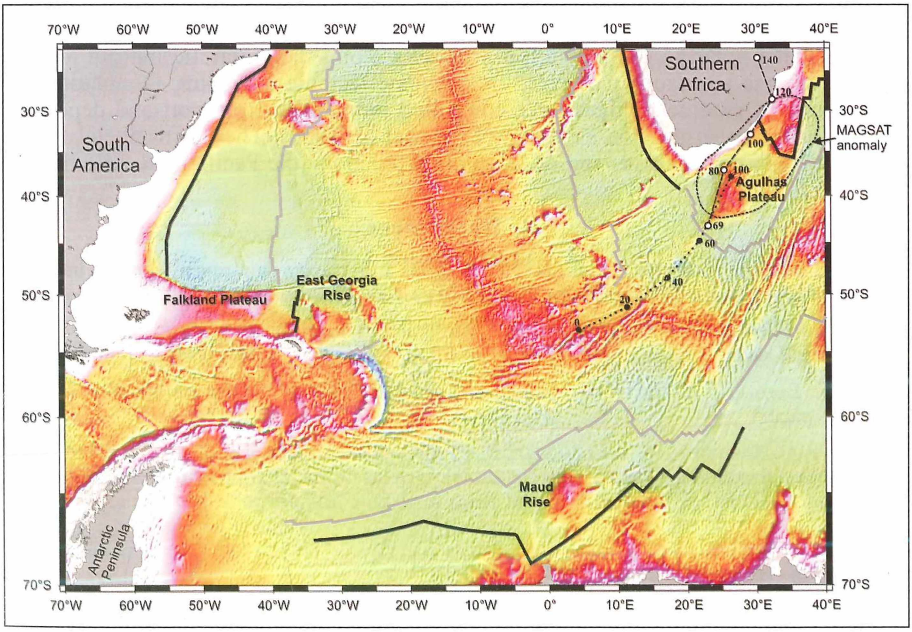

Fig. 2: Satellite-derived seafloor topography map of the southern Atlantic region. The Agulhas Plateau, Maud Rise and East Georgia Rise evolved as a single large igneous oceanic plateau after the Gondwana break-up and were separated by seafloor spreading centers. Isochrons M0 (120 Ma) are black lines; C34 (84 Ma) are gray lines. The Bouvet hot spot track is marked as dotted and dashed lines and black and white dots (two different models with time in million years).

dent openings around 155 million years ago with one in the central Weddell Sea and the other farther east in the Rijser-Larsen Sea. About 20 million years later the two ocean basins were connected, and after another 10 million years the South Atlantic between Africa and South America started to open (JOKAT et al., submitted paper).

3.2. Southeast Pacific Puzzle

The southeast Pacific region has been the focus of increasing geoscientific interest over the last years. Reasons for this interest are (1) the active geodynamic processes related to the Pacific-Antarctic and East-Pacific ridge systems, (2) the complicated plate tectonic kinematics of the region, and (3) the architecture and evolution of the Antarctic continental margin and its glacial-marine sedimentation cycles. The largest source of geodynamic activity stems from the fast-spreading ridge systems. Repeated reorientation of rotation poles and spreading axes created complex plate relations in the southeast Pacific. The southernmost Pacific, however, has been regarded as a region of tectonic inactivity since the Oligocene.

New seismic, gravimetric and magnetic data as well as geological sampling show that, even after the end of convergence between the Phoenix and the Antarctic plate, the Antarctic continental rise has been tectonically and magmatically active until recent times. Seismic and gravimetric surveys of a zone of dominant north-south striking gravity anomalies in the Bellingshausen Sea indicate the existence of an interplate convergence perpendicular to the margin (GOHL et al. 1997). An accreted sedimentary wedge within an asymmetric basement graben can be clearly identified. Overlying sediments provide an acoustic-stratigraphic record of the vertical basement deformation. Geophysical data from the Antarctic continental margin suggest a continuation of this tectonic feature from oceanic to continental crust.

The glacial-marine sedimentation processes along the Antarctic margin and the continental rise are strongly affected by the plate tectonic dynamics. Orientation and dimensions of basement ridges have controlled sedimentary transport and deposition of material from suspension currents (NITSCHE et al. 2000). They form nuclei for the growth of sediment mounds and drifts as observed along the Pacific-Antarctic margin.

4. References

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