vast majority of these transfer events happened before the evolution of multicellularity. Our multicellularity probably saved us from participating in the dirty business of lateral gene transfer so beloved by microbes.

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PERSPECTIVES: PLATE TECTONICS

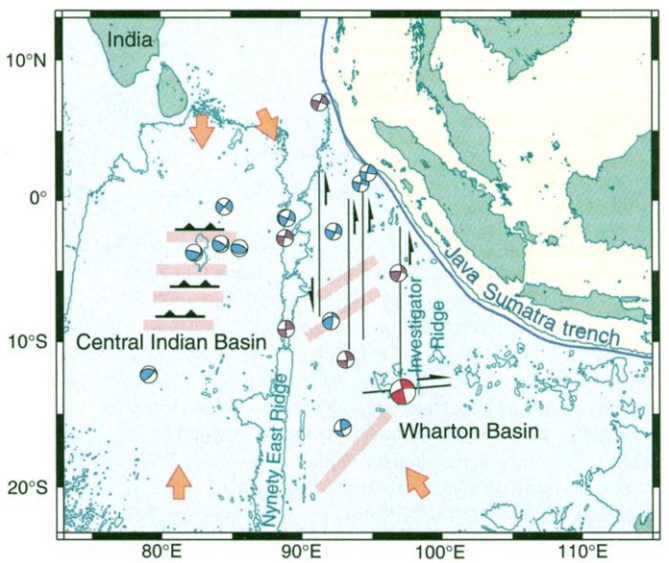
Indian Ocean Actively Deforms

Christine Deplus

According to plate tectonics, plates are rigid and deform only at their boundaries. There is, however, ample evidence of intraplate deformation in the Equatorial Indian Ocean. The deformation results from exceptionally high stresses in the oceanic lithosphere caused by the ongoing collision of India with Eurasia. Such intraplate deformation is commonly observed on the continents but not in the oceans, where deformation is usually localized at a narrow plate boundary rather than distributed over a wide area. The Indian Ocean thus offers a rare opportunity to study intraplate deformation of oceanic lithosphere.

Deformation in the Indian Ocean was first proposed in the 1970s (*1*) to resolve the difficulties in fitting global plate motion using a single rigid Indo-Australian plate. This traditionally defined plate is now considered as a composite plate, which includes three rigid or nearly rigid component plates and several deforming zones (*2*). The deforming zones may be described as diffuse plate boundaries, thus relaxing the fundamental assumption of plate tectonics that all oceanic plate boundaries are narrow (*2*, *3*). In the following, the term "intraplate" refers to earthquakes or deformation occurring within these large diffuse boundaries, with reference to the "classic" plate boundaries of the Indo-Australian plate.

The Equatorial Indian Ocean is known for its intraplate seismic activity and long-wavelength undulations in satellite-derived gravity data. Many earthquakes, with magnitude as large as 6 or 7, have occurred here during the last century (see the figure) (*4*). On 18 June 2000, an earthquake of magnitude 7.8 was registered in the Wharton Basin south of Cocos island (*5*). Earthquakes in the Central Indian Basin generally follow mechanisms different from those in the Wharton Basin. Their mechanisms indicate that the main compressive stress rotates from north-south in the Central Indian Basin to northwest-southeast in the Wharton Basin (*4*). In addition, the long-wavelength gravity undulations strike east-west in the Central Indian Basin and northeast-southwest in the Wharton Basin, in both cases roughly perpendicular to the compression axis. Numerical modeling of the Indo-Australian plate stress field (*6*, *7*) suggests that the rotation of the main compressive stress can be largely explained by the change in boundary conditions north of the Indo-Australian plate. The northward motion of India is resisted by the India-Asia collision, whereas the Wharton Basin freely subducts under the Java-Sumatra trench.



A large area of intraplate deformation. The compression axis in the Equatorial Indian Ocean (orange arrows) rotates from north-south in the Central Indian Basin to northwest-southeast in the Wharton Basin, yielding a different pattern of deformation in the two basins. Many large earthquakes have occurred during the last century [blue, Harvard CMT solutions (*13*); purple, from (*4*); pink, 18 June 2000 earthquake (*5*)]. In both basins, large-scale deformation may occur through buckling/folding perpendicular to the compression axis (long wavelength gravity undulations in light red). Brittle failure seems to occur along preexisting weakness directions (black), namely the north-south fracture zones and the east-west abyssal hill fabric.

The stress directions can thus be predicted reasonably well. The strain pattern is more difficult to assess, however, and requires field data from marine surveys or detailed source mechanism of recent earthquakes.

Most studies have focused on the Central Indian Basin. Here, tectonic deformation is characterized by long-wavelength (100 to 300 km) undulations of the oceanic basement—associated with the gravity undulations—and superimposed small-scale reverse faulting and folding of the crust and overlying sediments (*8*, *9*). We do not yet have enough data to determine the definitive cause of the long-wavelength undulations, but analog and numerical modeling suggests that it is caused by folding and buckling of the lithosphere (*9*, *10*).

Until recently, little was known about the deformation pattern in the Wharton Basin. The satellite-derived gravity undulations strike northeast-southwest and have wavelengths and amplitudes similar to those in the Central Indian Basin. They may again indicate folding and buckling of the lithosphere to accommodate northwest-southeast shortening. It remains unclear, however, whether the undulations are again associated with reverse faulting in the crust.

Some Wharton Basin earthquakes exhibit thrust mechanisms (indicative of reverse faulting), but most are strike slip. A marine

The author is at the Laboratoire Gravimétrie et Géodynamique, Institut de Physique du Globe de Paris and CNRS, 4, place Jussieu, 75252 Paris, France. E-mail: deplus@ipgp.jussieu.fr

survey in the northern part of the basin has provided direct evidence of active strike-slip faulting (*12*) at several north-south active faults. These faults have a present-day left-lateral movement and are reactivated fracture zones of a fossil spreading center. According to the seismicity farther north and south, the faults must be at least 1000 km long, reaching the Sumatra trench to the north.

The large magnitude of the 18 June 2000 Wharton Basin earthquake and the availability of high-quality digital data with good station coverage allowed Robinson *et al.* (*5*) to model the details of the source. The earthquake turns out to have an unusual mechanism: Two subevents simultaneously ruptured a nearly north-south plane and a plane nearly conjugate to the first. Rupture along the north-south plane was similar to the movement along the surveyed strike-slip faults 800 km farther northwest. Therefore, all the fracture zones in the northern Wharton Basin are probably reactivated by strike-slip faulting between the Nynety East ridge and the Investigator ridge (see the figure). The northern Wharton Basin thus appears to be cut into north-south slivers that subduct more and more easily the further east one goes (*12*). Rupture along the east-west plane introduces some northwest-southeast compressional deformation (*5*).

The east-west plane is consistent with the orientation of the abyssal hills of the oceanic lithosphere. The lithosphere thus deforms along preexisting weakness directions: the north-south fracture zones and the east-west abyssal hill fabric, both of which originate at the mid-ocean spreading centers. Note that in the Central Indian Basin, most of the reverse faults result from the reactivation of the abyssal hill fabric (*8*). In both basins, the lithosphere may deform at large scale by buckling and folding perpendicular to the compression axis, but brittle failure of its upper part occurs along preexisting weakness directions (see the figure).

Some questions are still open. Is rupture along north-south and east-west directions specific to this earthquake or not? The June 18, 2000 earthquake is located in a broad area covered by numerous ridges and seamounts. Is there an influence of volcanism in the deformation process in this area? And how can southwest-northeast folding of the Wharton Basin lithosphere be compatible with brittle failure along north-south and east-west directions? To resolve these questions, we need to better understand the role of preexisting features in the mechanical response of an oceanic lithosphere when it is subjected to high compressive stress.

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14. I thank Hélène Hébert and Michel Diament for their contributions.

PERSPECTIVES: MOLECULAR BIOLOGY

Getting p53 Out of the Nucleus

Vanesa Gottifredi and Carol Prives

A cell becomes cancerous because it has sustained a number of genetic changes. To avoid accruing such changes, cells need a protective surveillance system. The tumor suppressor protein p53 is a transcription factor that switches on a series of protective genes when the cell is exposed to stressful events. Many solid tumors contain defective forms of p53 that are unable to stop cells from proliferating when, for example, their DNA has been damaged. The current picture of p53, however, requires that we view this transcription factor as working in partnership with its negative regulator MDM2 (see the figure). The p53–MDM2 partnership appears to operate rather simply: Activated p53 switches on the *MDM2* gene, and the MDM2 protein (an E3 ubiquitin ligase with a RING finger motif) then represses p53 activity by inducing its degradation in proteasomes (*1*).

Both p53 and MDM2 move between the nucleus and cytoplasm in the cell. They possess nuclear localization signals (NLSs) and so are found predominantly in the nucleus. But they must also be able to leave the nucleus and enter the cytoplasm under certain conditions. To exit the nucleus through the nuclear pores, proteins bigger than 40 kilodaltons must bind to nuclear export receptors; and to bind to these receptors, proteins must possess a nuclear export signal (NES). Both MDM2 (*2*) and p53 (*3*) contain an NES—the p53 NES resides in its carboxyl terminus between amino acids 320 and 355 (*3*). It comes as something of a surprise, then, to hear from Zhang and Xiong on page 1910 of this issue that p53 possesses another NES in its amino terminus, between amino acids 11 and 27 (*4*). This amino-terminal region becomes phosphorylated at several residues in response to different types of cellular stress such as DNA damage (*5*), and phosphorylation of at least one of these residues correlates with reduced nuclear export of p53.

The identification of a second NES in the amino terminus of p53 is intriguing because it is not clear what the different NES signals in p53 and MDM2 do. Also unclear is precisely how phosphorylation regulates the nuclear export of p53. Finally, there is plenty of room to speculate about why p53 needs to be exported from the nucleus at all.

A few years ago, Roth and colleagues set out to identify the tasks of the p53 and MDM2 NES (*2*). They carried out heterokaryon assays in which two different cell types (one with and one without MDM2) were fused together, resulting in two nuclei within a mutual cytoplasm. After incubating the heterokaryons with a protein synthesis inhibitor, they found that the MDM2-deficient nucleus had acquired MDM2, demonstrating that MDM2 was able to move from one nucleus into the other. Importantly, their data also revealed that shuttling of MDM2 from the nucleus into the cytoplasm was required for degradation of p53 (*2*). Moreover, MDM2 with either a defective NLS or NES could not degrade p53 (*6*), implicating MDM2 itself in the movement of p53 to the cytoplasm. This hypothesis came under challenge when an NES was discovered in the carboxyl-terminal domain of p53 (*3*), which is the region responsible for the assembly of p53 monomers into the active tetramer. The p53 NES is presumed to be masked and inactive when p53 forms a tetramer, but functional when p53 is either a monomer or a dimer. Although attractive, this model is difficult to prove because it is nearly impossible to determine the oligomeric state of the scant amount of p53 in unstressed cells. Then, two groups (*7*, *8*) put forward a unifying hypothesis, prompted by the somewhat unexpected observation that the NES of MDM2 is dispensable for nuclear export of p53, whereas the RING finger motif of MDM2 is not. This suggests that as MDM2 adds ubiquitin molecules (ubiquitination) onto p53 in the nucleus, the NES of p53 becomes unmasked, enabling ubiquitinated p53 to move into the cytoplasm and to be degraded by proteasomes.

The authors are in the Department of Biological Sciences, Columbia University, New York, NY 10027, USA. E-mail: clp3@columbia.edu