Do Continental Lithospheric Discontinuities Control Tectonic Plate Motion Directions?

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Plate-tectonic reconstructions use rotational (Euler) poles about which plates rotate in small circle patterns, producing oceanic fracture zones. Oceanic fracture zones are contiguous with transform faults. Because oceanic lithosphere older than ~200 Ma is preferentially destroyed by subduction, pre-Mesozoic plate-tectonic reconstructions lack such constraints from oceanic fracture zones. Based on high-resolution bathymetry, geological and geophysical data, with particular emphasis on the Red Sea-Gulf of Aden system, some fracture zones are shown to be contiguous with pre-existing discontinuities in adjacent continents, while others develop parallel to those. Combined with results from existing analog and numerical models, continental rift zones and oceanic spreading ridges that are initially oblique to these discontinuities are demonstrated to evolve into orientations perpendicular to them, while fracture zones and transform faults develop parallel to them. Consequently, oceanic spreading directions, or the exact plate movement directions, are controlled by pre-existing continental lithospheric discontinuities, while other factors such as slab pull control the general direction. This hypothesis constitutes a paradigm shift, from the widespread belief that transform fault and fracture zone orientations are controlled by plate motions, to one where some are inherited from pre-existing continental discontinuities and control the exact directions of plate movements. If so, identifying such discontinuities in ancient continental lithosphere may constrain plate motions in deep geologic time.

Plain language summary

Plate-tectonic reconstructions use rotational (Euler) poles about which plates rotate in small circle patterns, producing oceanic fracture zones. Oceanic fracture zones are contiguous with transform faults, which separate segments of oceanic spreading ridges, where new oceanic lithosphere (crust and uppermost mantle) forms. Because oceanic lithosphere older than ~200 million years is preferentially destroyed by subduction, pre-Mesozoic plate-tectonic reconstructions lack such constraints from oceanic fracture zones. Based on high-resolution bathymetry, geological and geophysical data, some fracture zones are shown to be contiguous with pre-existing discontinuities in adjacent continents. Combined with results from existing analog models, continental rift zones and oceanic spreading ridges that are initially oblique to these discontinuities are demonstrated to evolve into orientations perpendicular to them, while fracture zones and transform faults develop parallel to them. Consequently, oceanic spreading directions, or plate movement directions, are partially controlled by pre-existing continental lithospheric discontinuities. This hypothesis constitutes a paradigm shift, from the widespread belief that transform fault and fracture zone orientations are controlled by plate motions, to one where they are inherited from pre-existing continental discontinuities, and partially control plate movement directions. If so, identifying such discontinuities in ancient continental lithosphere may constrain plate motions in deep geologic time.