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Transient transform faults on the Reykjanes Ridge: Why a linear oblique axis is favored there over an orthogonal ridge-transform system

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The Reykjanes Ridge is a key setting to study how ridge segmetation and transform faults form, evolve and disappear. The Reykjanes Ridge initiated following Greenland-Eurasia continental breakup, spreading orthogonally in a linear configuration without offsets. It continued stably spreading in this configuration for about 18 Myr until Greenland was joined to North America resulting in a $\sim 30^{\circ}$ change in opening direction. The ridge then abruptly reconfigured to an orthogonally-spreading stair-step pattern with new ridge segments offset by a series of transform faults. Promptly after forming the stair-step pattern the ridge began to eliminate the just-formed offsets and transform faults to re-establish its original linear configuration although this required the ridge to now spread obliquely as plate motion continued without change in the new direction. The reconfiguration progressed diachronously and systematically from north to south but in a punctuated manner. Currently, the reconfiguration to a linear and oblique axis is almost complete to the Bight transform fault, a distance of almost 1000 km from Iceland. Here we explore geologic mechanisms by which the original plate boundary formed in a linear geometry, became segmented and offset, and what may have driven the reassembly of the axis back to its original configuration even though this required elimination of an orthogonal ridge-transform system and its replacement by a linear obliquely-spreading ridge. We find that kinematic effects, as seen at other spreading centers, can explain the breakup of the ridge into an offset stair-step configuration. This was most likely effected through a series of short-lived propagating ridges. The reassembly of the axis back to its original linear configuration, however, implies a strong control by the earlier plate boundary. We propose that the deep low viscosity "damp" melting regime of the original axis persisted in its linear configuration following the abrupt change in opening direction. This linear melting regime was likely maintained by the propagation of buoyant small-scale upwelling instabilities along it and guided the reassembly of the axis back to its original configuration. Individual ridge segments migrated laterally so as to shorten transform fault offsets to reform the linear axis. A systematic regional gradient in mantle melting away from Iceland may have propelled the small-scale convective instabilities southward and helped configure the original linear axis and guide reassembly of the axis following its fragmentation. The reconfigurations of the Reykjanes Ridge highlight the importance of plate kinematic effects and small-scale convective processes within the ridge melting regime in controlling the segmentation and evolution of divergent and transform plate boundaries.