Paleostress Analysis of Post-Alleghanian Brittle Faults from an Exposure in the Putnam-Nashoba Terrane, Eastern Connecticut

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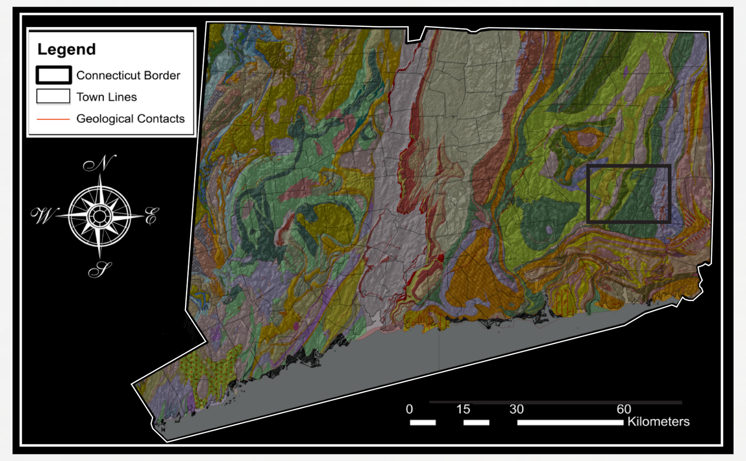
Abstract

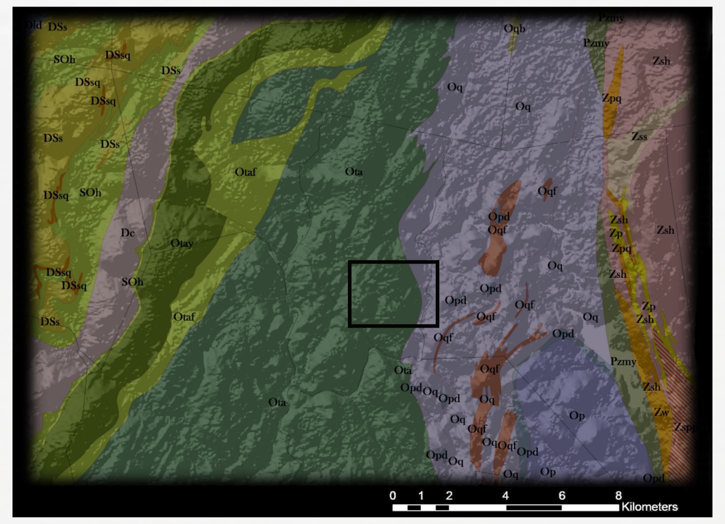
New construction in Lisbon, CT, has exposed large and conveniently accessible roadcuts with a dense and heterogeneous collection of faults. The roadcuts, which are just west of the Tatnic fault, are well-layered gneiss of the Tatnic Hill Formation in the Putnam-Nashoba terrane. Fault-slip data from 90 faults were collected in order to understand the post-Alleghanian brittle deformation.

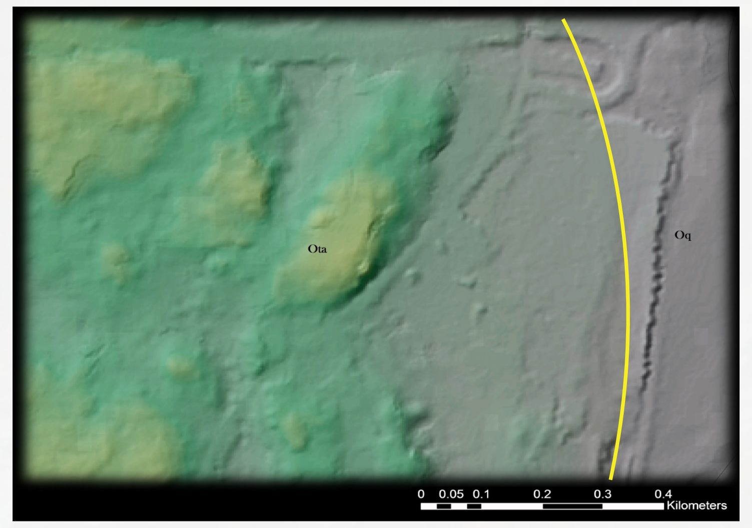
Fault-slip data were separated into phases using the program T-Tecto and arranged chronologically based upon age relations identified from fault surfaces in the field. Phase 1 consists of a conjugate set of ~NW-SE-striking normal faults coupled with a conjugate set of ~N-S-striking sinistral strike-slip faults and ~E-W-striking dextral strike-slip faults. Phase 2 consists of ~NW-SE-striking strike-slip faults, interpreted as reactivated surfaces from the normal faults of phase 1. Phase 3 lacks a conjugate set and consists of faults that are most likely reactivated surfaces. Each conjugate set from phase 1 was evaluated separately because drag folds observed in the field suggest the strike-slip faults (renamed phase 1b) postdate the normal faults (renamed phase 1a). Phase 1a displays a ~NE-SW σ 3, phase 1b displays a ~NW-SE σ1, phase 2 displays a ~N-S σ1, and phase 3 displays a ~ENE-WSW σ1.

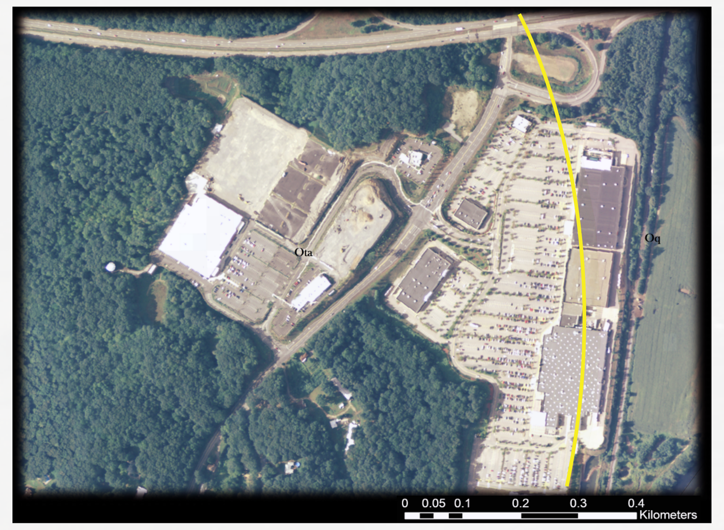
The stress orientations are interpreted as related to Mesozoic rifting and subsequent development of the passive margin. Phase 1 stress orientations indicate a change from NE-SW (phase 1a) extension to NW-SE (phase 1b) compression. Phase 1b possibly developed synchronously with structural inversion of the rift basins. Main-phase rifting with NW-SE extension is not seen, suggesting that phase 1a is the transition from rifting to structural inversion. Phase 2 stress orientations indicate N-S compression and are consistent with other observations in New England. Phase 3 stress orientations indicate ENE-WSW compression possibly characterized by the present-day state of stress. Previous work has seen structural inversion in synrift strata in the Fundy rift basin and southeastern United States characterized by NE-striking reverse faults; however, we see structural inversion in basement characterized by conjugate strike-slip faults.

Background

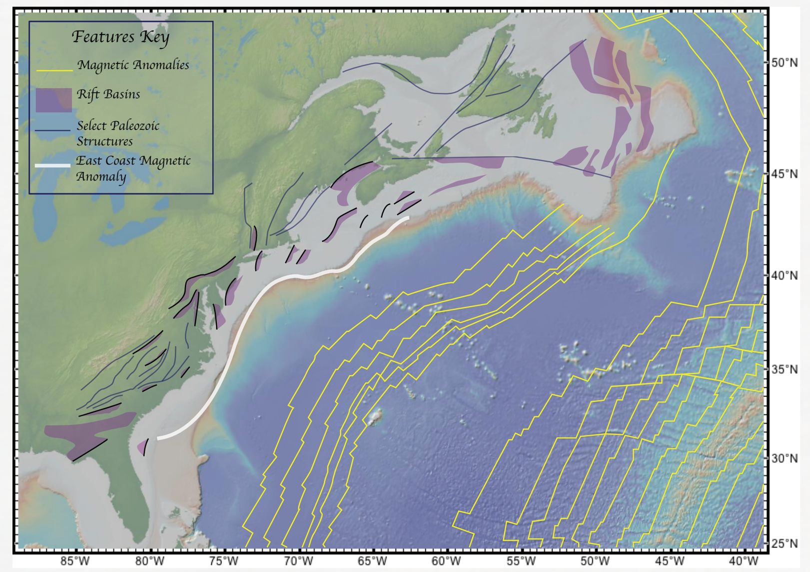








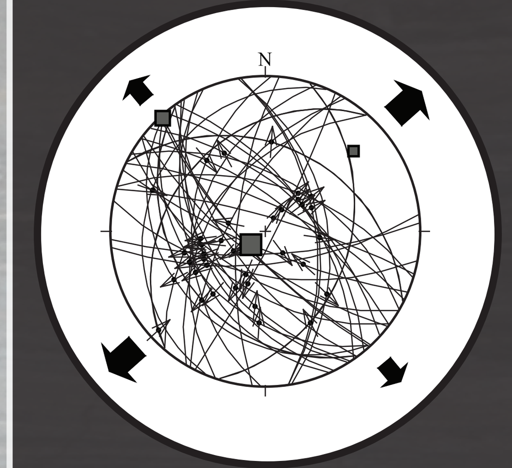
Rifting

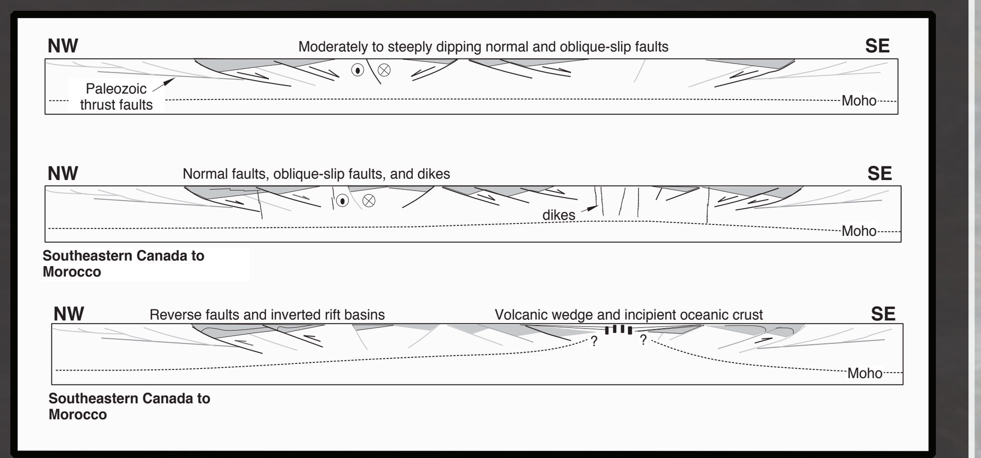


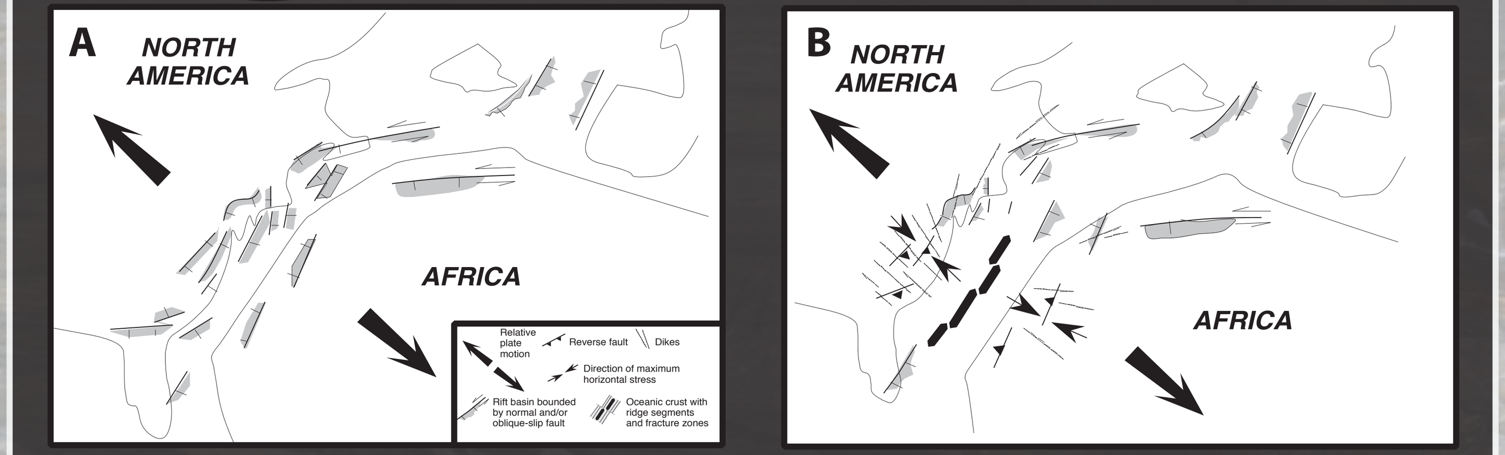
From the Middle Triassic to the Early Jurassic, rifting fragmented the supercontinent of Pangea and formed the passive margin of North America. The east coast of North America contains rift basins related to the extension and attenuation of the lithosphere during early rifting (Withjack and Schlische, 1998). As Africa and North America drifted apart, the polar reversals of Earths' magnetic field were recorded in rocks along the sea floor. These magnetic anomalies record the trajectories of the continents as far back as 155 Ma (M-25). Seismic and well data suggest early sea-floor spreading began before 175 Ma.

Figure modified from Withjack and Schlische (2005).

Phase 1a — Transition from Rifting to Inversion

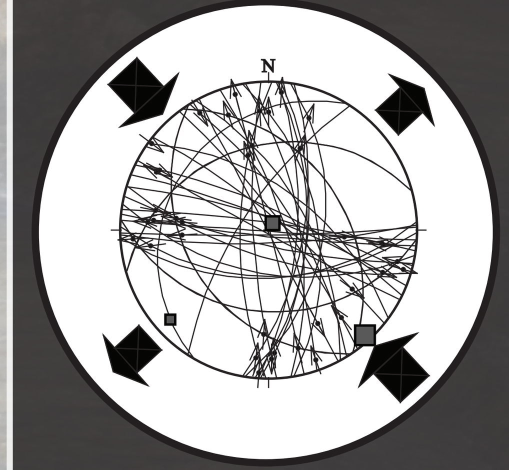


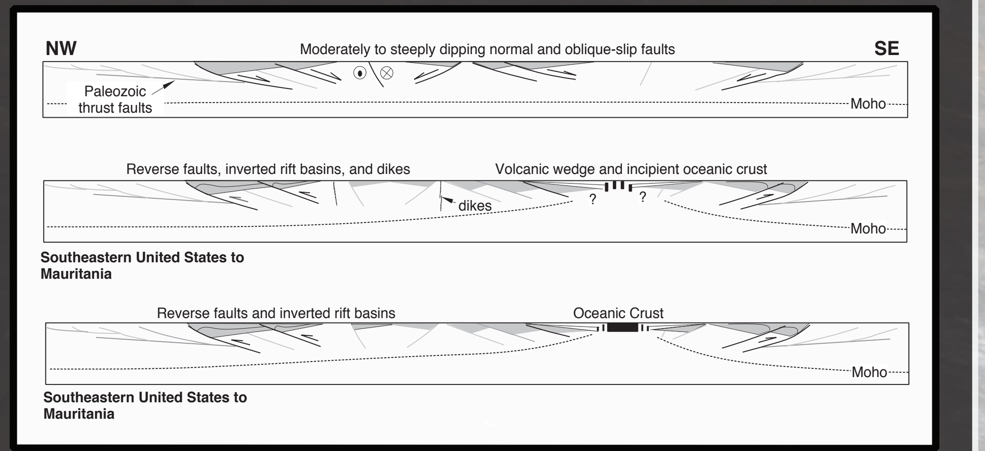




(A) Northeast-striking rift basins start to develop, subside and fill with sediments during the Middle to Late Triassic.
(B) The transition from rifting to inversion begins before the early Cretaceous.
(Upper Right) (Top) The rift basins in northeastern North America develop. (Middle) The normal boundary faults remain active and the ENA magmatic activity favored the emplacement of northeast-striking diabase dikes. (Bottom) Rifting ceased before the late Early Jurassic to early Middle Jurassic and Inversion occurred in southeastern Canada before or during the Early Cretaceous.
Figures taken from (Withjack et al., 1998)

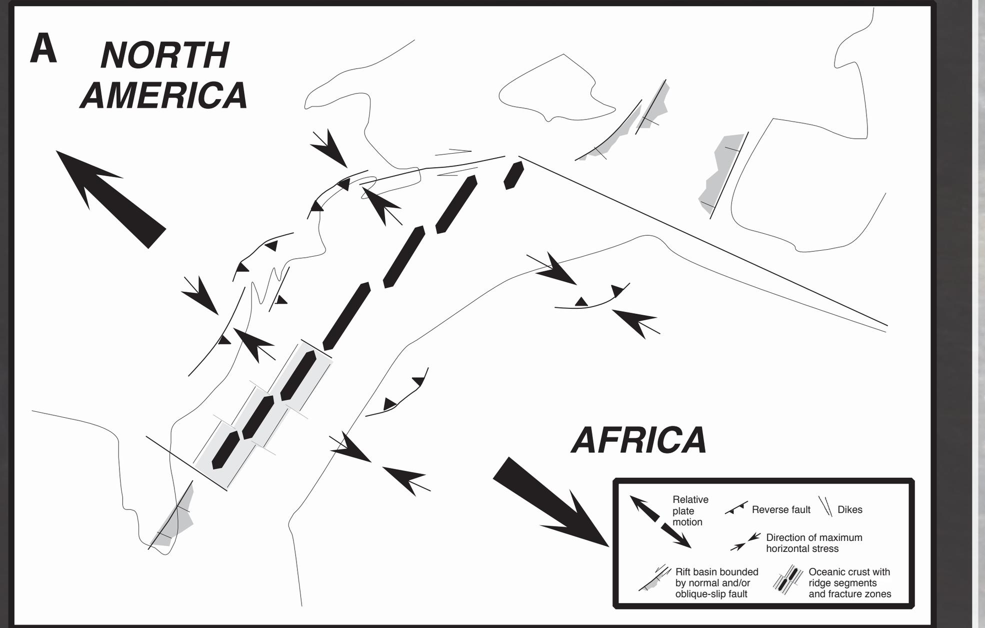
Phase 1b — Inversion



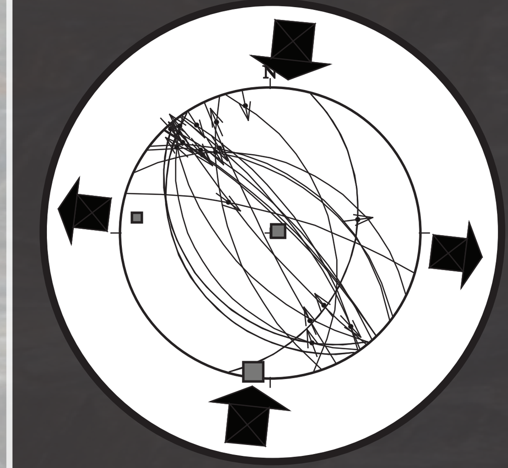


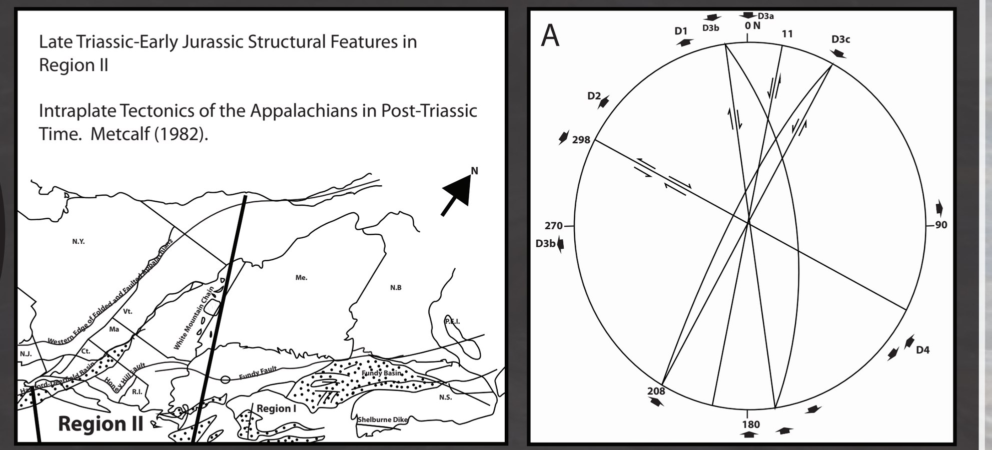
(A) The Early Jurassic to Early Cretaceous activity following ENA magmatic activity.
(Upper Right) (Top) In the southeastern United States, rifting begins during the Triassic. (Middle) Rifting ceases and northeast-striking reverse faults and associated folds develop. ENA magmatic activity led to the emplacement of north to northwest-striking dikes. (Bottom) Full-fledged drifting began between the southeastern United States and western Africa.

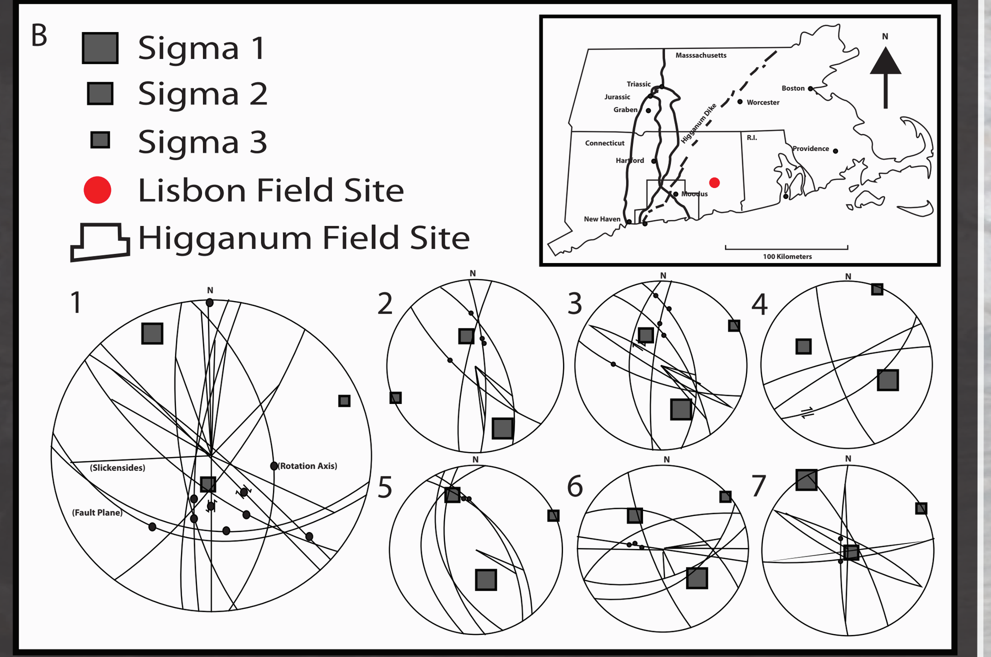
Figures taken from (Withjack et al., 1998).



Phase 2 — Elsewhere in New England





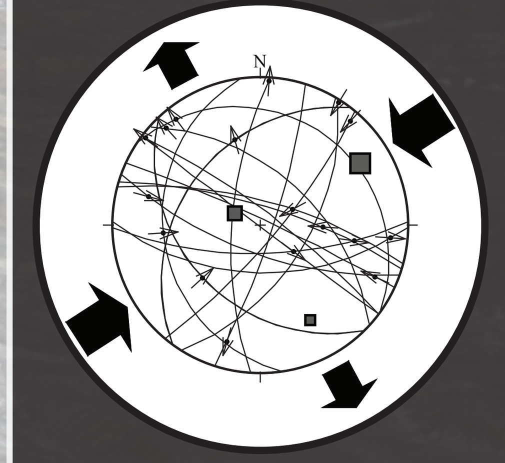


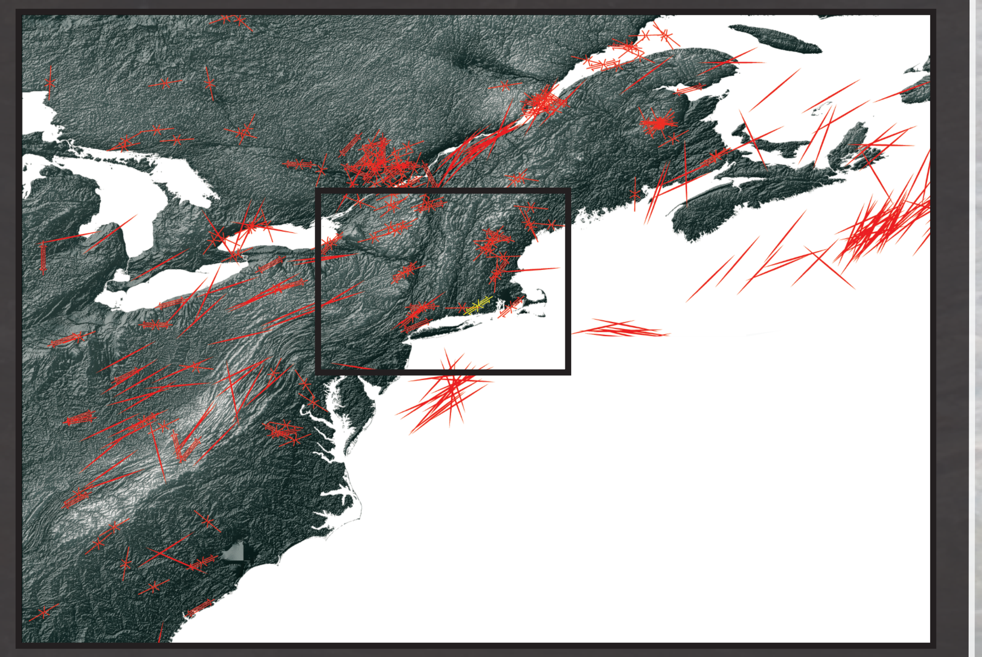
(A) Stereoplot of the mean fault stress orientations found in Region II. D3a shows a 000° to 350° σ1. The data come from strike-slip faults found within the Hartford-Deerfield Basin.
(B) Stereoplots of the mean stress orientations derived from reactivated joints of the Higganum Dike in southern Connecticut. Each plot is from a segment of the Higganum Dike (1 in the northeast and 7 in the southwest). The plots show a general σ1 trending NNW - SSE.

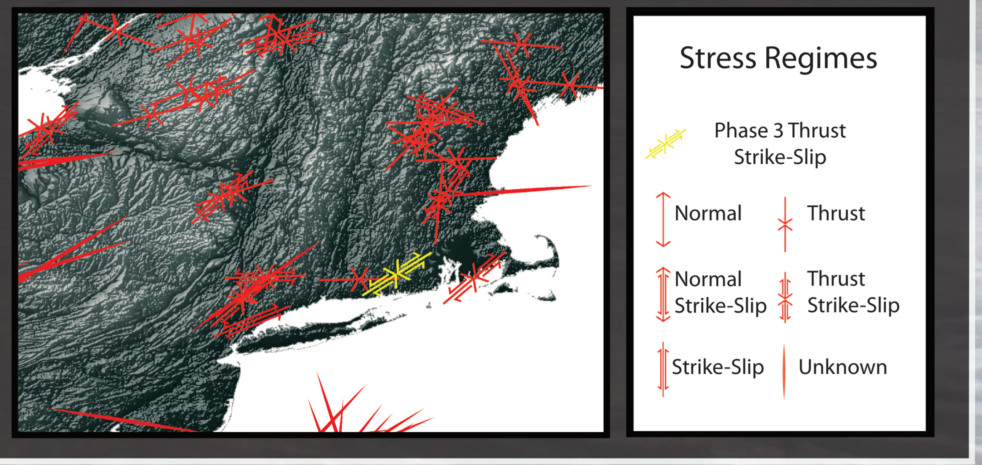
Note: Evidence indicating a north-south σ1 in crystalline rocks of Connecticut and Massachusetts is lacking (Piepul 1975).

Figures in (A) taken from (Metcalf, 1982). Figures (B) taken from (Sawyer and Carroll, 1982).

Phase 3 — Contemporary Stress



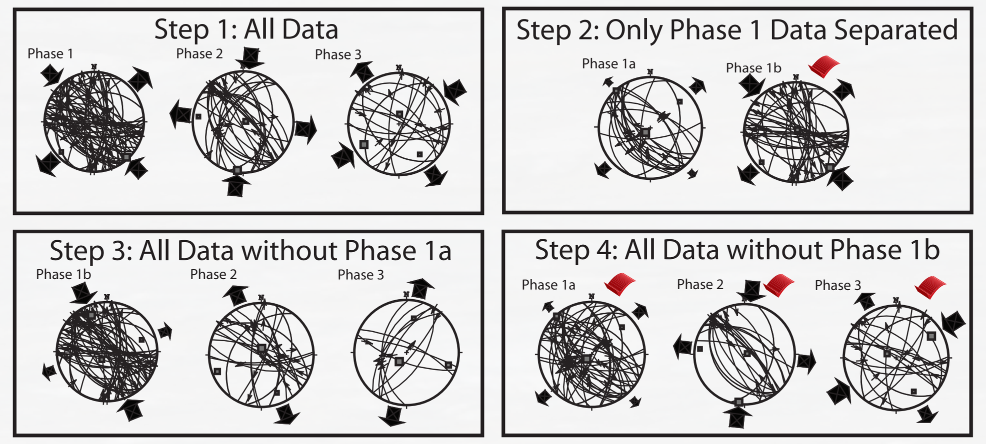




(Upper Right) Map of the contemporary stresses found in New England. The compilation of stress data comes from earthquake focal mechanisms, well bore breakouts and drilling-induced fractures, in-situ stress measurements, and young geologic data.
(Right) Enlarged regional map surrounding the field site in Lisbon, CT. The general trend of the contemporary state of stress for the region is consistent with phase 3.

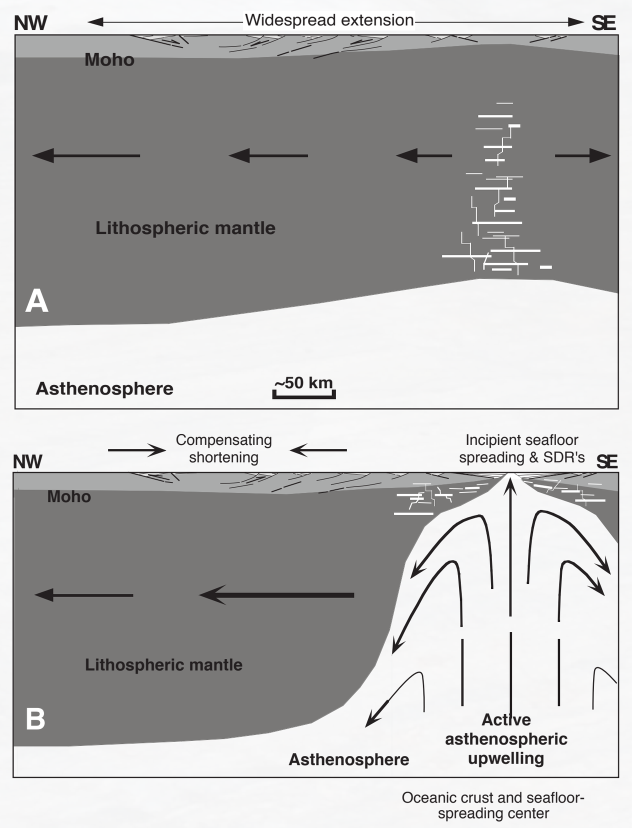
World Stress data provided by; Heidbach, O., Tingay, M., Barth, A., Reinecker, J., Kurfeß, D. and Müller, B., The World Stress Map database release 2008 doi:10.1594/GFZ.WSM.Rel2008, 2008.

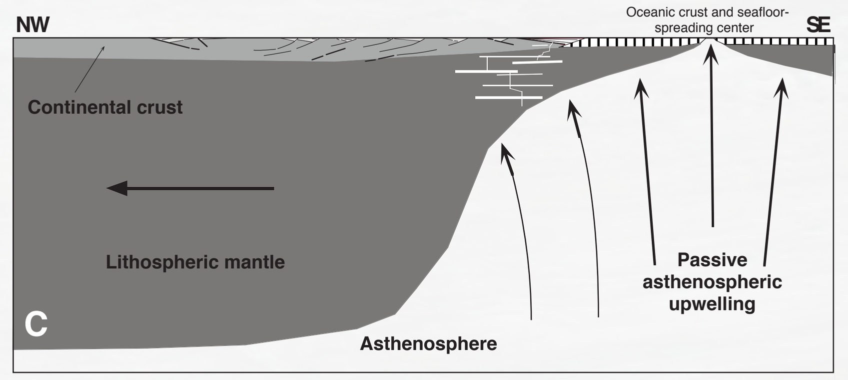
Methods



Step 1: All 114 faults from Lisbon were analyzed in T-Tecto
Step 2: Faults from phase 1 were analyzed separately from the rest of the data because age relations in the field suggest the conjugate strike-slips (phase 1b) post-date the conjugate dip-slips (phase 1a). T-Tecto assigned the data into the same phase because both conjugate sets can fit into the same symmetrical stress regime.
Step 3: All of the data except for phase 1a were analyzed.
Step 4: All of the data except for phase 1b were analyzed.
Final Results: (Red ticks = selected phases)
Phase 1a from step 4 is recognized as the first phase because of a robust conjugate set of dip-slip faults consistent with age relations observed in the field.
Phase 1b from step 2 is recognized as the second phase because of a robust conjugate set of strike-slip faults that is consistent with age relations observed in the field.
Phase 2 from step 4 is recognized as the third phase because cross cutting relations suggest the faults are reactivated surfaces from phase 1a.
Phase 3 from step 4 is recognized as the final phase because of a northeast trending σ1 that is consistent with the contemporary stress in the region.
Red: Strike-slip striae **Green:** Dip-slip striae
(A) A fault plane with two sets of striae. The horizontal striae (strike-slip) dominates the fault plane while the vertical striae (dip-slip) is depressed in a cavity. Strike-slip motion would have post-dated dip-slip motion.
(B) A fault plane revealing large drag folds resulting from dip-slip motion. Strike-slip striae is superimposed on the drag fold.

Tectonic Model for Central North America





A) Early rifting. Distant plate-tectonic forces produce divergent lithospheric displacements.

B) Late rifting. Lithosphere is substantially thinned. Gravitational-body forces and traction forces associated with the hot, low-density asthenospheric upwelling increase substantially. In response, lithospheric displacements near the upwelling exceed those far from the upwelling, causing shortening (inversion) in the intervening zone.

C) Early drifting. Lithospheric displacements far from upwelling increase, eventually equaling those near the upwelling. Most shortening/inversion ceases, and the asthenospheric upwelling becomes passive.

Figures Taken From (Withjack et al., 1998).

Discussion

- The four phases represent data collected from crystalline basement.
- Phase 1a suggests a transition from rifting to structural inversion.
- Phase 1b suggests structural inversion.
- Phase 2 is observed elsewhere in New England.
- Phase 3 fits the current state of stress in New England.

References

Metcalf, T.P., 1982, Intraplate Tectonics of the Appalachians in Post-Triassic Time I: Wesleyan University.
Piepul, R. G., 1975, Analysis of Jointing and Faulting at the Southern End of the Eastern Border Fault, Connecticut: University of Masschusetts.
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Withjack, M., Schlische, R., and Olsen, P., 1998, Diachronous Rifting, Drifting, and Inversion on the Passive Margin of Central Eastern North America: An Analog for Other Passive Margins: AAPG bulletin, v. 82, p. 817–835.