231-5

Recovering 'Fossilised' Strain:

reconstructing the evolving strain field above the locked Cascadia megathrust over multiple earthquake cycles using Anisotropy Of Magnetic Susceptibility (AMS)

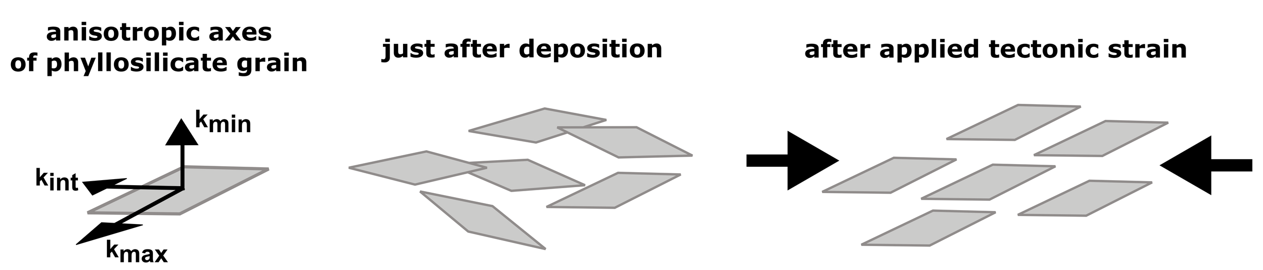
Christopher J. Rowan
Department of Geology,
Kent State University,
325 S. Lincoln St., Kent, OH 44242.
crowan5@kent.edu
http://all-geo.org/chris_rowan

- Tectonic fabrics developed in deforming offshore sediments can potentially extend observations of the Cascadia forearc's evolving strain field in space and time, beyond that currently available from geodetic (GPS) measurements.
- Paleomagnetically reoriented AMS data from three marine cores from the Cascadia margin show (1) an increase in degree of anisotropy from trench to coast; (2) upper core fabric orientations consistent with the contemporary deformation field, where they overlap; and (3) similar down-core variations in the inferred paleoshortening direction, with major jumps in shortening azimuth consistent in their timing with the offshore paleoseismic record[1].
- Magnetic fabric data can potentially extend observations of interseismic strain offshore into the most strongly locked region of the megathrust, over multiple earthquake cycles, and contribute to refined estimates of the future seismic hazard on the Cascadia subduction zone, and other deforming regions worldwide.

Acknowledgements

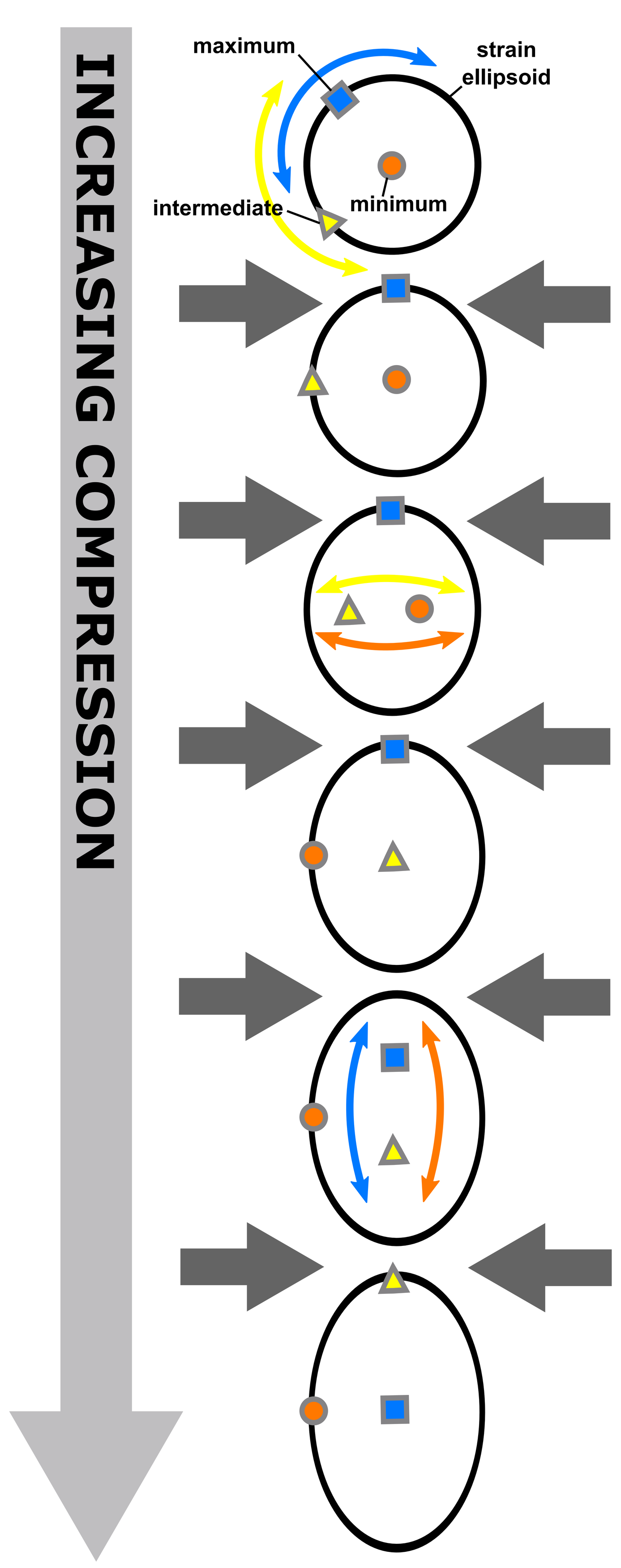
The author would like to thank Joe Stoner and Maziet Cheseby, for allowing access to cores held at the Oregon State University Marine Geology Repository (grant number is OCE-0962077), and Mike Jackson for arranging instrument time for sample analysis at the Institute for Rock Magnetism, University of Minnesota.

AMS and tectonic fabrics



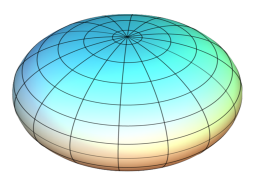
In deforming areas, phyllosilicate grains in fine-grained sediments are physically rotated into alignment, in response to ambient tectonic strain. Measurements of bulk anisotropy of magnetic susceptibility (AMS) reveal distinct tectonic fabrics even when macroscopic deformation features are absent[2-4]. Fabrics aligned with the geodetically derived strain field can develop within ~25 years of deposition[5].

Progressively larger strains will further modify the initial bedding fabric by grain realignments. In regions of compression and shortening, such as the Cascadia forearc, **the maximum susceptibility axis is perpendicular to the shortening axis except at very high strains.**



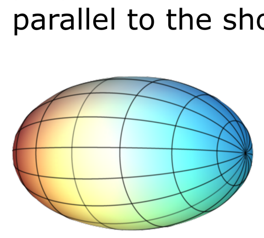
Type 1 fabric: just after deposition, settling and compaction leads to vertical minimum susceptibility axis k_{min}, with intermediate and maximum axes k_{int} and k_{max} randomly oriented in the bedding plane.

Type 2 fabric: horizontal compression causes preferred alignment of k_{max} perpendicular to the shortening axis.



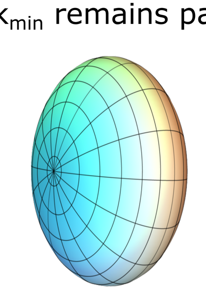
OBLATE: kmax≈kint>kmin

Type 3 fabric: further compression can rotate grains around a horizontal axis so that k_{int} and k_{min} swap positions. k_{max} remains perpendicular and k_{min} is now parallel to the shortening axis.



PROLATE: kmax>kint≈kmin

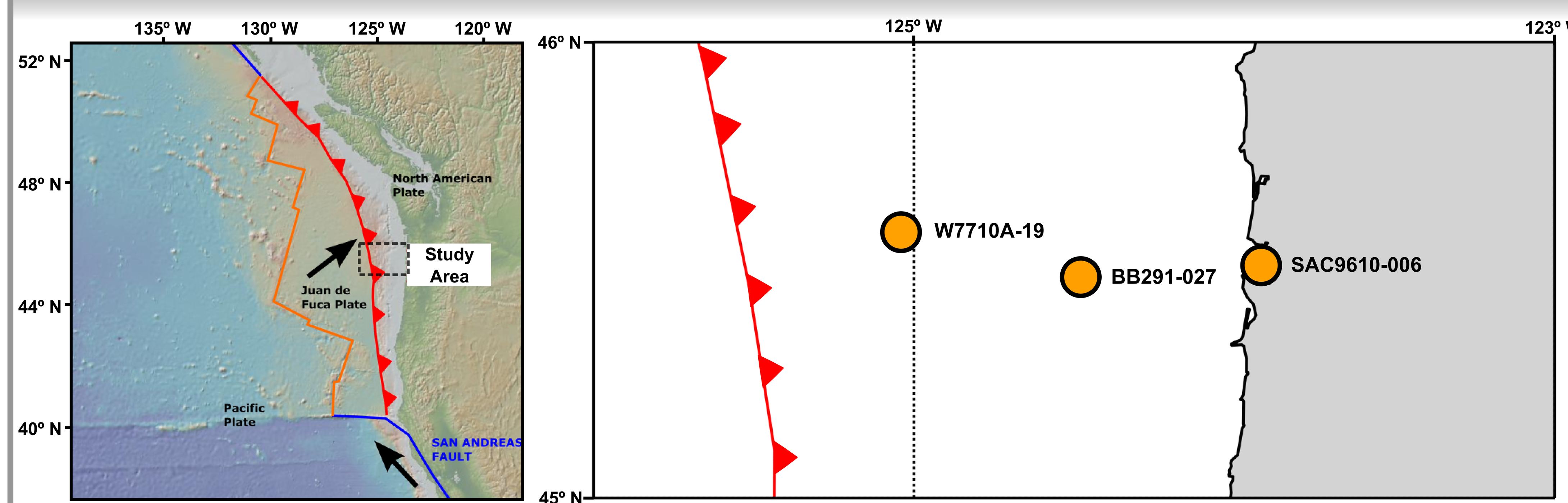
Type 4 fabric: stretching in the vertical plane can cause k_{max} and k_{int} to swap positions. kint is now perpendicular to the shortening axis k_{min} remains parallel.

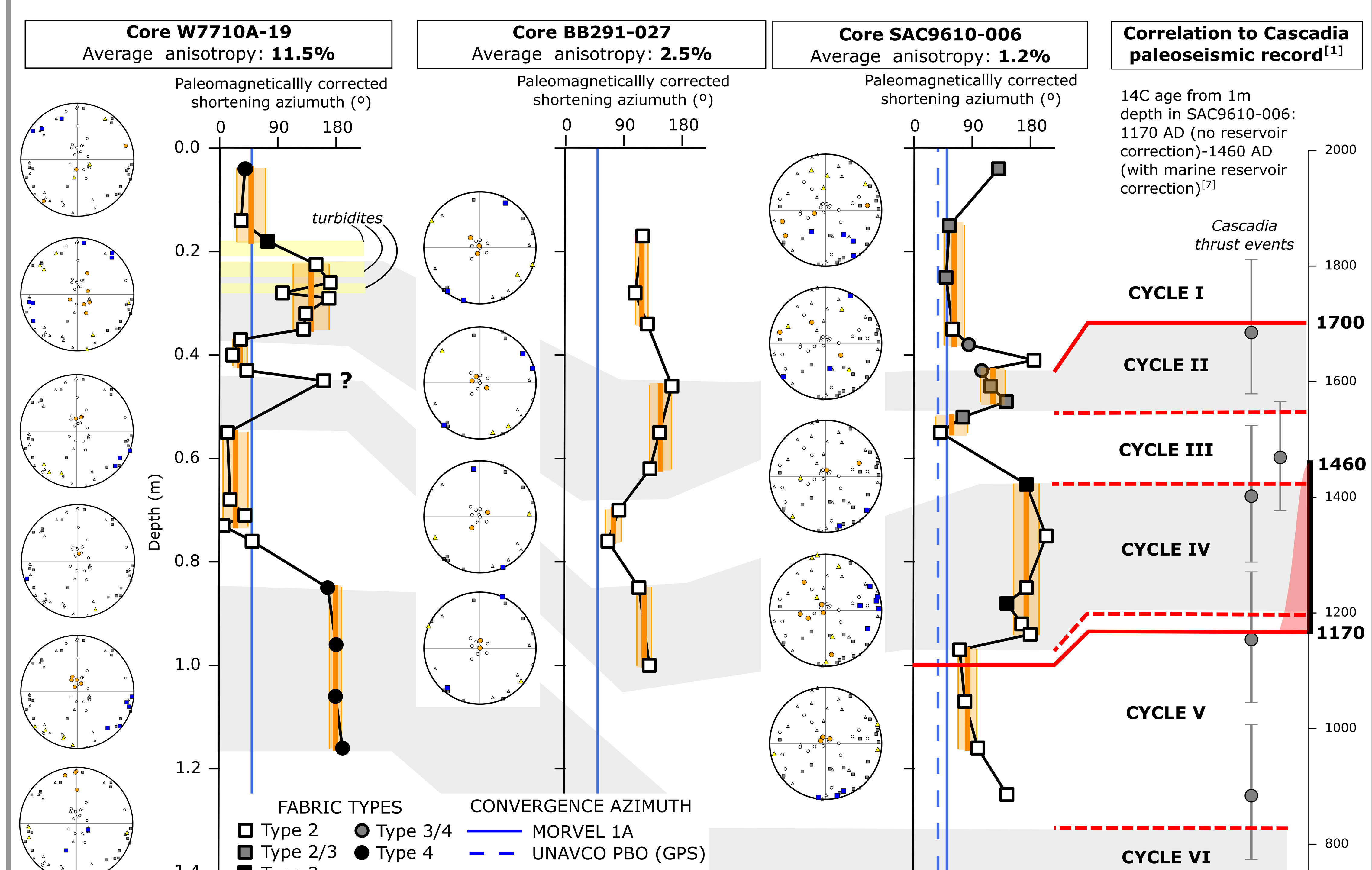


OBLATE: kmax≈kint>kmin

modified from [6]

Core sampling and analysis

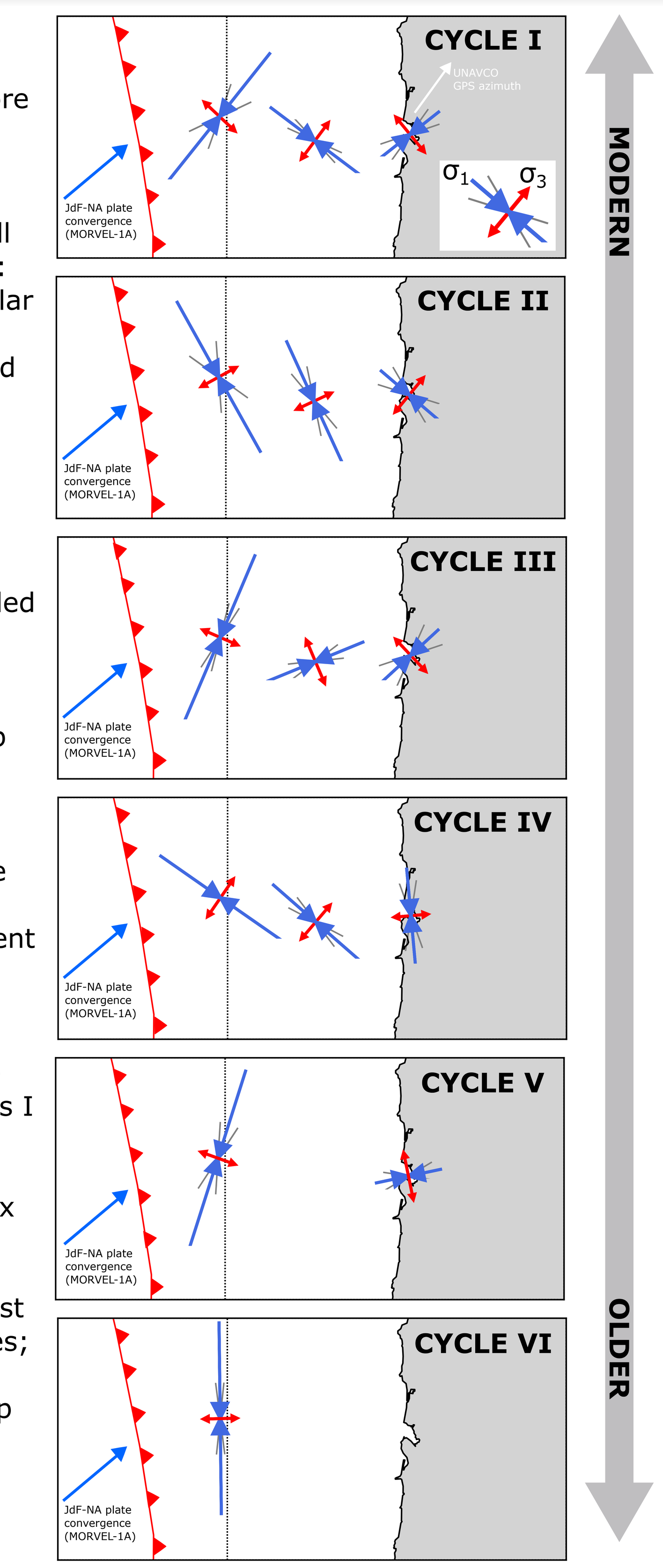




- Three marine sediment cores on a transect across the Cascadia forearc at ~45ºN were selected from the collection held at the Marine Geology Repository, Oregon State University. 7cm^3 samples were extracted from each core at an average interval of 5-10 cm.
- AMS was measured on a Kappabridge KLY-4 Susceptibility Bridge, followed by stepwise AF demagnetisation on a 2G Enterprises cryogenic magnetometer to isolate the characteristic remanent magnetisation.
- Most samples yielded fabrics consistent with a shortening-related magnetic lineation developed within the bedding plane. These fabrics were reoriented into a geographic reference frame for each core using their mean paleomagnetic declinations.
- All cores show a common down-core pattern of variation in the inferred paleoshortening axis, with intervals of relative stability separated by abrupt jumps in the average bearing. In W7710A-19, the youngest such transition is associated with a turbidite horizon.

Paleostrain evolution

- Six intervals with distinct paleostress patterns were reconstructed from the core records.
- Inferred shortening directions (σ_1) seem to fall into two broad categories: largely trench-perpendicular and close to the plate convergence direction, and highly oblique, almost trench-parallel.
- Trench-parallel σ_1 may indicate a tectonic fabric formed by gravitational collapse of a weakly coupled margin, with a lineation developing parallel to the extension direction σ_3, rather than strain build up on a strongly coupled margin.
- Spatial variation along the transect varies between cycles; σ_1 is fairly consistent from trench to coast in cycles II, III, IV, but switches between trench-perpendicular and trench-parallel directions in cycles I and V.
- This may reflect a complex evolving strain field in response to changes in coupling on the megathrust between earthquake cycles; further data from other margin transects may help to unravel this spatial pattern.



References

1. Goldfinger, C. et al., 2012, Turbidite event history: Methods and implications for Holocene paleoseismicity of the Cascadia subduction zone: US Geological Survey Professional Paper 1611-F
2. Kissel C. et al., 1986, Magnetic fabric in "undeformed" marine clays from compressional zones: Tectonics, v. 5, no. 5, p. 769–781.
3. Mattei, M. et al., 1997, Magnetic fabric of weakly deformed clay-rich sediments in the Italian peninsula: Relationship with compressional and extensional tectonics: Tectonophysics, v. 271, no. 1, p. 107–122.
4. Soto, R. et al, 1997. Reliability of magnetic fabric of weakly deformed mudrocks as a palaeostress indicator in compressive settings: Journal of Structural Geology, v. 31, no. 5, p. 512–522, doi: 10.1016/j.jsg.2009.03.006.
5. Larrasoaña, J.C., Gómez-Paccard, M., Giralt, S., and Roberts, A.P., 2011, Rapid locking of tectonic magnetic fabrics in weakly deformed mudrocks: Tectonophysics, v. 507, no. 1-4, p. 16–25, doi: 10.1016/j.tecto.2011.05.003.
6. Winkler, A. et al., 1997. The magnetic anisotropy of rocks: principles, techniques and geodynamic applications in the Italian peninsula. Annali di Geophysica, v. XL, no. 3, p. 729-740.
7. McManus, J. et al., 1998. Sediment sources and the history of accumulation in Tillamook Bay, Oregon. Final Report, Tillamook Bay National Estuary Project Sedimentation Study.

Oblate and prolate spheroid images by Sam Derbyshire (http://en.wikipedia.org/wiki/User:Sam_Derbyshire/Gallery).