



William Ellsworth

Professor (Research) of Geophysics, Emeritus

 Curriculum Vitae available Online

Bio

BIO

My research interests can be broadly defined as the study of active faults, the earthquakes they generate and the physics of the earthquake source. A major objective of my work is to improve our knowledge of earthquake hazards through the application of physics-based understanding of the underlying processes. As Co-Director of the Stanford Center for Induced and Triggered Seismicity, my students, postdocs and I conduct multi-disciplinary studies into the causes and consequences of anthropogenic earthquakes in a wide variety of settings. I have also long been committed to earthquake risk reduction, specifically through the transfer of scientific understanding of the hazard to people, businesses, policymakers and government agencies. Before coming to Stanford in 2015, I was a research geophysicist at the U. S. Geological Survey in Menlo Park, California for more than 40 years where I focused on problems of seismicity, seismotectonics, probabilistic earthquake forecasting, and earthquake source processes

ACADEMIC APPOINTMENTS

- Emeritus Faculty, Acad Council, Geophysics

ADMINISTRATIVE APPOINTMENTS

- Geophysicist, U. S. Geological Survey, (1971-2008)
- Chief, Branch of Seismology, U. S. Geological Survey, (1982-1988)
- Consulting Professor of Geophysics, Stanford University, (1992-2008)
- Chief Scientist, Earthquake Hazards Team, U. S. Geological Survey, (2002-2005)
- Senior Research Geophysicist, U. S. Geological Survey, (2008-2015)
- Professor (Research), Stanford University, (2015- present)
- Co-Director, Stanford Center for Induced and Triggered Seismicity, Stanford University, (2015-2023)

HONORS AND AWARDS

- Meritorious Service Award, U. S. Department of the Interior (1990)
- Gilbert Fellow, U. S. Geological Survey (1993)
- Fellow, American Geophysical Union (2001)
- Distinguished Service Award, U. S. Department of the Interior (2010)
- EarthScope National Lecturer, National Science Foundation (2012)
- Gutenberg Lecture, American Geophysical Union (2018)
- Harry Fielding Reid Medal, Seismological Society of America (2021)

BOARDS, ADVISORY COMMITTEES, PROFESSIONAL ORGANIZATIONS

- President, Seismological Society of America (2007 - 2009)

PROFESSIONAL EDUCATION

- Ph.D, Massachusetts Institute of Technology , Geophysics (1978)
- M. S., Geophysics , Stanford University (1971)
- B.S., Stanford University , Physics (1971)

Teaching

COURSES

2022-23

- Introductory Seismology: GEOPHYS 130 (Aut)
- Seismology: GEOPHYS 385Q (Aut, Win, Spr)

2021-22

- Earthquake Seismology, Deformation, and Stress: GEOPHYS 385L (Sum)
- Seismology: GEOPHYS 385Q (Aut, Win, Spr, Sum)

2020-21

- Earthquake Seismology, Deformation, and Stress: GEOPHYS 385L (Aut, Win, Sum)
- Introductory Seismology: GEOPHYS 130 (Aut)
- Seismology: GEOPHYS 385Q (Aut, Win, Sum)

STANFORD ADVISEES

Doctoral Dissertation Reader (AC)

Axel Wang, Taiyi Wang

Publications

PUBLICATIONS

- **Reactivation of Precambrian Faults by Deep Wastewater Injection in Midland Basin, Texas, and Performance Evaluation of Seismic Response Areas** *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*
Woo, J., Ellsworth, W. L.
2023; 113 (6): 2543-2556
- **The physical mechanisms of induced earthquakes** *NATURE REVIEWS EARTH & ENVIRONMENT*
Moein, M. A., Langenbruch, C., Schultz, R., Grigoli, F., Ellsworth, W. L., Wang, R., Rinaldi, A., Shapiro, S.
2023; 4 (12): 847-863
- **Adaptive Coda-Wave Imaging With Voronoi Tessellation** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Mao, S., Ellsworth, W. L., Beroza, G. C.
2023; 128 (8)
- **En echelon faults reactivated by wastewater disposal near Musreau Lake, Alberta** *GEOPHYSICAL JOURNAL INTERNATIONAL*
Schultz, R., Park, Y., Suarez, A., Ellsworth, W. L., Beroza, G. C.
2023; 235 (1): 417-429
- **Disposal From In Situ Bitumen Recovery Induced the M-L 5.6 Peace River Earthquake** *GEOPHYSICAL RESEARCH LETTERS*
Schultz, R., Woo, J., Pepin, K., Ellsworth, W. L., Zebkar, H., Segall, P., Gu, Y., Samsonov, S.

2023; 50 (6)

- **Induced seismicity red-light thresholds for enhanced geothermal prospects in the Netherlands** *GEOTHERMICS*
Schultz, R., Muntendam-Bos, A., Zhou, W., Beroza, G. C., Ellsworth, W. L.
2022; 106
- **A comprehensive suite of earthquake catalogues for the 2016-2017 Central Italy seismic sequence.** *Scientific data*
Chiaraluce, L., Michele, M., Waldhauser, F., Tan, Y. J., Herrmann, M., Spallarossa, D., Beroza, G. C., Cattaneo, M., Chiarabba, C., De Gori, P., Di Stefano, R., Ellsworth, W., Main, et al
2022; 9 (1): 710
- **QuakeFlow: a scalable machine-learning-based earthquake monitoring workflow with cloud computing** *GEOPHYSICAL JOURNAL INTERNATIONAL*
Zhu, W., Hou, A., Yang, R., Datta, A., Mousavi, S., Ellsworth, W. L., Beroza, G. C.
2022; 232 (1): 684-693
- **DevelNet: Earthquake Detection on Develocorder Films with Deep Learning: Application to the Rangely Earthquake Control Experiment** *SEISMOLOGICAL RESEARCH LETTERS*
Wang, K., Ellsworth, W., Beroza, G. C., Zhu, W., Rubinstein, J. L.
2022; 93 (5): 2515-2528
- **Reply to: Multiple induced seismicity mechanisms at Castor underground gas storage illustrate the need for thorough monitoring.** *Nature communications*
Cesca, S., Stich, D., Grigoli, F., Vuan, A., Lopez-Comino, J. A., Niemez, P., Blanch, E., Dahm, T., Ellsworth, W. L.
2022; 13 (1): 3445
- **Earthquake Phase Association Using a Bayesian Gaussian Mixture Model** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Zhu, W., McBrearty, I. W., Mousavi, S., Ellsworth, W. L., Beroza, G. C.
2022; 127 (5)
- **DeepShake: Shaking Intensity Prediction Using Deep Spatiotemporal RNNs for Earthquake Early Warning** *SEISMOLOGICAL RESEARCH LETTERS*
Datta, A., Wu, D. J., Zhu, W., Cai, M., Ellsworth, W. L.
2022; 93 (3): 1636-1649
- **Physics-Based Model Reconciles Caldera Collapse Induced Static and Dynamic Ground Motion: Application to Kilauea 2018** *GEOPHYSICAL RESEARCH LETTERS*
Wang, T. A., Coppess, K. R., Segall, P., Dunham, E. M., Ellsworth, W.
2022; 49 (8)
- **Statistical bounds on how induced seismicity stops.** *Scientific reports*
Schultz, R., Ellsworth, W. L., Beroza, G. C.
1800; 12 (1): 1184
- **A Strategy for Choosing Red-Light Thresholds to Manage Hydraulic Fracturing Induced Seismicity in North America** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Schultz, R., Beroza, G. C., Ellsworth, W. L.
2021; 126 (12)
- **Machine-learning-facilitated earthquake and anthropogenic source detections near the Weiyuan Shale Gas Blocks, Sichuan, China** *EARTH AND PLANETARY PHYSICS*
Zhou, P., Ellsworth, W. L., Yang, H., Tan, Y., Beroza, G. C., Sheng, M., Chu, R.
2021; 5 (6): 501-519
- **Seismicity at the Castor gas reservoir driven by pore pressure diffusion and asperities loading.** *Nature communications*
Cesca, S., Stich, D., Grigoli, F., Vuan, A., Lopez-Comino, J. A., Niemez, P., Blanch, E., Dahm, T., Ellsworth, W. L.
2021; 12 (1): 4783
- **Ambient noise Love wave attenuation tomography for the LASSIE array across the Los Angeles basin.** *Science advances*
Liu, X., Beroza, G. C., Yang, L., Ellsworth, W. L.
2021; 7 (22)
- **A risk-based approach for managing hydraulic fracturing-induced seismicity.** *Science (New York, N.Y.)*
Schultz, R., Beroza, G. C., Ellsworth, W. L.

2021; 372 (6541): 504–7

- **Relative earthquake location procedure for clustered seismicity with a single station** *GEOPHYSICAL JOURNAL INTERNATIONAL*
Grigoli, F., Ellsworth, W. L., Zhang, M., Mousavi, M., Cesca, S., Satriano, C., Beroza, G. C., Wiemer, S.
2021; 225 (1): 608–26
- **Depth Constraints on Coseismic Velocity Changes From Frequency-Dependent Measurements of Repeating Earthquake Waveforms** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Sheng, Y., Ellsworth, W. L., Lellouch, A., Beroza, G. C.
2021; 126 (2)
- **Comparison between Distributed Acoustic Sensing and Geophones: Downhole Microseismic Monitoring of the FORGE Geothermal Experiment** *SEISMOLOGICAL RESEARCH LETTERS*
Lellouch, A., Lindsey, N. J., Ellsworth, W. L., Biondi, B. L.
2020; 91 (6): 3256–68
- **Risk-Informed Recommendations for Managing Hydraulic Fracturing-Induced Seismicity via Traffic Light Protocols** *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*
Schultz, R., Beroza, G., Ellsworth, W., Baker, J.
2020; 110 (5): 2411–22
- **Hydraulic Fracturing-Induced Seismicity** *REVIEWS OF GEOPHYSICS*
Schultz, R., Skoumal, R. J., Brudzinski, M. R., Eaton, D., Baptie, B., Ellsworth, W.
2020; 58 (3)
- **Revisiting the Timpson Induced Earthquake Sequence: A System of Two Parallel Faults** *GEOPHYSICAL RESEARCH LETTERS*
Wang, K., Ellsworth, W., Beroza, G. C.
2020; 47 (15)
- **Earthquake transformer-an attentive deep-learning model for simultaneous earthquake detection and phase picking.** *Nature communications*
Mousavi, S. M., Ellsworth, W. L., Zhu, W., Chuang, L. Y., Beroza, G. C.
2020; 11 (1): 3952
- **Rescuing Legacy Seismic Data FAIR'ly** *SEISMOLOGICAL RESEARCH LETTERS*
Hwang, L. J., Ahern, T., Ebinger, C. J., Ellsworth, W. L., Euler, G. G., Okal, E. A., Okubo, P. G., Walter, W. R.
2020; 91 (3): 1339–40
- **Empirical and Synthetic Approaches to the Calibration of the Local Magnitude Scale, M-L, in Southern Kansas** *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*
Al-Ismail, F., Ellsworth, W. L., Beroza, G. C.
2020; 110 (2): 689–97
- **Machine-Learning-Based Analysis of the Guy-Greenbrier, Arkansas Earthquakes: A Tale of Two Sequences** *GEOPHYSICAL RESEARCH LETTERS*
Park, Y., Mousavi, S., Zhu, W., Ellsworth, W. L., Beroza, G. C.
2020; 47 (6)
- **Rapid Characterization of the July 2019 Ridgecrest, California, Earthquake Sequence From Raw Seismic Data Using Machine-Learning Phase Picker** *GEOPHYSICAL RESEARCH LETTERS*
Liu, M., Zhang, M., Zhu, W., Ellsworth, W. L., Li, H.
2020; 47 (4)
- **Value at Induced Risk: Injection-Induced Seismic Risk From Low-Probability, High-Impact Events** *GEOPHYSICAL RESEARCH LETTERS*
Langenbruch, C., Ellsworth, W. L., Woo, J., Wald, D. J.
2020; 47 (2)
- **HIGH-PASS FILTERS TO REDUCE THE EFFECTS OF BROAD ATMOSPHERIC CONTRIBUTIONS IN SBAS INVERSIONS: A CASE STUDY IN THE DELAWARE BASIN**
Pepin, K., Zebker, H. A., Ellsworth, W., IEEE
IEEE.2020: 1030-1033
- **Velocity-Based Earthquake Detection Using Downhole Distributed Acoustic Sensing-Examples from the San Andreas Fault Observatory at Depth** *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*

- Lellouch, A., Yuan, S., Ellsworth, W. L., Biondi, B.
2019; 109 (6): 2491–2500
- **Unsupervised Clustering of Seismic Signals Using Deep Convolutional Autoencoders** *IEEE GEOSCIENCE AND REMOTE SENSING LETTERS*
Mousavi, S., Zhu, W., Ellsworth, W., Beroza, G.
2019; 16 (11): 1693–97
 - **Rapid Earthquake Association and Location** *SEISMOLOGICAL RESEARCH LETTERS*
Zhang, M., Ellsworth, W. L., Beroza, G. C.
2019; 90 (6): 2276–84
 - **Triggering of the Pohang, Korea, Earthquake (M-w 5.5) by Enhanced Geothermal System Stimulation** *SEISMOLOGICAL RESEARCH LETTERS*
Ellsworth, W. L., Giardini, D., Townend, J., Ge, S., Shimamoto, T.
2019; 90 (5): 1844–58
 - **Unsupervised Large-Scale Search for Similar Earthquake Signals** *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*
Yoon, C. E., Bergen, K. J., Rong, K., Elezabi, H., Ellsworth, W. L., Beroza, G. C., Bailis, P., Levis, P.
2019; 109 (4): 1451–68
 - **Source Parameter Variability of Intermediate-Depth Earthquakes in Japanese Subduction Zones** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Chu, S., Beroza, G. C., Ellsworth, W. L.
2019; 124 (8): 8704–25
 - **Robust Stress Drop Estimates of Potentially Induced Earthquakes in Oklahoma: Evaluation of Empirical Green's Function** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Yoshimitsu, N., Ellsworth, W. L., Beroza, G. C.
2019; 124 (6): 5854–66
 - **Managing injection-induced seismic risks.** *Science (New York, N.Y.)*
Lee, K., Ellsworth, W. L., Giardini, D., Townend, J., Ge, S., Shimamoto, T., Yeo, I., Kang, T., Rhie, J., Sheen, D., Chang, C., Woo, J., Langenbruch, et al
2019; 364 (6442): 730–32
 - **Seismology with Dark Data: Image-Based Processing of Analog Records Using Machine Learning for the Rangely Earthquake Control Experiment** *SEISMOLOGICAL RESEARCH LETTERS*
Wang, K., Ellsworth, W. L., Beroza, G. C., Williams, G., Zhang, M., Schroeder, D., Rubinstein, J.
2019; 90 (2): 553–62
 - **Foreshocks and Mainshock Nucleation of the 1999 M-w 7.1 Hector Mine, California, Earthquake** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Yoon, C. E., Yoshimitsu, N., Ellsworth, W. L., Beroza, G. C.
2019; 124 (2): 1569–82
 - **The 2013-2016 Induced Earthquakes in Harper and Sumner Counties, Southern Kansas (vol 108, pg 674, 2018)** *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*
Rubinstein, J. L., Ellsworth, W. L., Dougherty, S. L.
2018; 108 (6): 3699–3700
 - **Nucleation of the 1999 Izmit earthquake by a triggered cascade of foreshocks** *NATURE GEOSCIENCE*
Ellsworth, W. L., Bulut, F.
2018; 11 (7): 531–+
 - **The 2013-2016 Induced Earthquakes in Harper and Sumner Counties, Southern Kansas** *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*
Rubinstein, J. L., Ellsworth, W. L., Dougherty, S. L.
2018; 108 (2): 674–89
 - **A Systematic Assessment of the Spatiotemporal Evolution of Fault Activation Through Induced Seismicity in Oklahoma and Southern Kansas** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Schoenball, M., Ellsworth, W. L.
2017; 122 (12): 10189–206

- **Stress drops of induced and tectonic earthquakes in the central United States are indistinguishable.** *Science advances*
Huang, Y., Ellsworth, W. L., Beroza, G. C.
2017; 3 (8): e1700772
- **Geodetic Slip Model of the 3 September 2016 M-w 5.8 Pawnee, Oklahoma, Earthquake: Evidence for Fault-Zone Collapse** *SEISMOLOGICAL RESEARCH LETTERS*
Pollitz, F. F., Wicks, C., Schoenball, M., Ellsworth, W., Murray, M.
2017; 88 (4): 983–93
- **Seismicity During the Initial Stages of the Guy-Greenbrier, Arkansas, Earthquake Sequence** *Journal of Geophysical Research – Solid Earth*
Yoon, C. E., Huang, Y., Ellsworth, W. L., Beroza, G. C.
2017
- **A new strategy for earthquake focal mechanisms using waveform-correlation-derived relative polarities and cluster analysis: Application to the 2014 Long Valley Caldera earthquake swarm** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Shelly, D. R., Hardebeck, J. L., Ellsworth, W. L., Hill, D. P.
2016; 121 (12): 8622-8641
- **3-D velocity structure in southern Haiti from local earthquake tomography** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Douilly, R., Ellsworth, W. L., Kissling, E., Freed, A. M., Deschamps, A., de Lepinay, B. M.
2016; 121 (12): 8813-8832
- **Seismic-Hazard Forecast for 2016 Including Induced and Natural Earthquakes in the Central and Eastern United States** *SEISMOLOGICAL RESEARCH LETTERS*
Petersen, M. D., Mueller, C. S., Moschetti, M. P., Hoover, S. M., Llenos, A. L., Ellsworth, W. L., Michael, A. J., Rubinstein, J. L., McGarr, A. F., Rukstales, K. S.
2016; 87 (6): 1327-1341
- **Surface uplift and time-dependent seismic hazard due to fluid injection in eastern Texas** *SCIENCE*
Shirzaei, M., Ellsworth, W. L., Tiampo, K. F., Gonzalez, P. J., Manga, M.
2016; 353 (6306): 1416-1419
- **USGS scientists open to change** *SCIENCE*
Beroza, G. C., Ellsworth, W. L., McNutt, M. K.
2016; 353 (6303): 998
- **Stress drop estimates of potentially induced earthquakes in the Guy-Greenbrier sequence** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Huang, Y., Beroza, G. C., Ellsworth, W. L.
2016; 121 (9): 6597-6607
- **Scaling relation between earthquake magnitude and the departure time from P wave similar growth** *GEOPHYSICAL RESEARCH LETTERS*
Noda, S., Ellsworth, W. L.
2016; 43 (17): 9053-9060
- **Fluid-faulting evolution in high definition: Connecting fault structure and frequency-magnitude variations during the 2014 Long Valley Caldera, California, earthquake swarm** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Shelly, D. R., Ellsworth, W. L., Hill, D. P.
2016; 121 (3): 1776-1795
- **Geophysics. Coping with earthquakes induced by fluid injection.** *Science*
McGarr, A., Bekins, B., Burkardt, N., Dewey, J., Earle, P., Ellsworth, W., Ge, S., Hickman, S., Holland, A., Majer, E., Rubinstein, J., Sheehan, A.
2015; 347 (6224): 830-831
- **Stress Transfer by the 2008 M-w 6.4 Achaia Earthquake to the Western Corinth Gulf and Its Relation with the 2010 Efpalio Sequence, Central Greece** *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*
Segou, M., Ellsworth, W. L., Parsons, T.
2014; 104 (4): 1723-1734
- **Injection-induced earthquakes.** *Science*
Ellsworth, W. L.
2013; 341 (6142): 1225942-?

- **Earthquake anniversary. Halfway through Reid's cycle and counting.** *Science (New York, N.Y.)*
Ellsworth, W. L.
2006; 312 (5771): 203-4
- **Optimizing correlation techniques for improved earthquake location** *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*
Schaff, D. P., Bokelmann, G. H., ELLSWORTH, W. L., Zankerka, E., Waldhauser, F., Beroza, G. C.
2004; 94 (2): 705-721
- **Apparent break in earthquake scaling due to path and site effects on deep borehole recordings** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Ide, S., Beroza, G. C., Prejean, S. G., ELLSWORTH, W. L.
2003; 108 (B5)
- **Fault structure and kinematics of the Long Valley Caldera region, California, revealed by high-accuracy earthquake hypocenters and focal mechanism stress inversions** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Prejean, S., Ellsworth, W., Zoback, M., Waldhauser, F.
2002; 107 (B12)
- **High-resolution image of Calaveras Fault seismicity** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Schaff, D. P., Bokelmann, G. H., Beroza, G. C., Waldhauser, F., ELLSWORTH, W. L.
2002; 107 (B9)
- **Observations of earthquake source parameters at 2 km depth in the Long Valley caldera, eastern California** *BULLETIN OF THE SEISMOLOGICAL SOCIETY OF AMERICA*
Prejean, S. G., ELLSWORTH, W. L.
2001; 91 (2): 165-177
- **Observation of the seismic nucleation phase in the Ridgecrest, California, earthquake sequence** *GEOPHYSICAL RESEARCH LETTERS*
Ellsworth, W. L., Beroza, G. C.
1998; 25 (3): 401-404
- **Detailed observations of California foreshock sequences: Implications for the earthquake initiation process** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Dodge, D. A., Beroza, G. C., ELLSWORTH, W. L.
1996; 101 (B10): 22371-22392
- **Properties of the seismic nucleation phase** *Symposium on Seismic Source Parameters - From Microearthquakes to Large Events, at the General Assembly of the European-Seismological-Commission*
Beroza, G. C., ELLSWORTH, W. L.
ELSEVIER SCIENCE BV.1996: 209-27
- **FORESHOCK SEQUENCE OF THE 1992 LANDERS, CALIFORNIA, EARTHQUAKE AND ITS IMPLICATIONS FOR EARTHQUAKE NUCLEATION** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Dodge, D. A., Beroza, G. C., ELLSWORTH, W. L.
1995; 100 (B6): 9865-9880
- **SEISMIC EVIDENCE FOR AN EARTHQUAKE NUCLEATION PHASE** *SCIENCE*
ELLSWORTH, W. L., Beroza, G. C.
1995; 268 (5212): 851-855
- **STABILITY OF CODA WAVE ATTENUATION DURING THE LOMA-PRIETA, CALIFORNIA, EARTHQUAKE SEQUENCE** *JOURNAL OF GEOPHYSICAL RESEARCH-SOLID EARTH*
Beroza, G. C., Cole, A. T., ELLSWORTH, W. L.
1995; 100 (B3): 3977-3987
- **SEISMICITY REMOTELY TRIGGERED BY THE MAGNITUDE 7.3 LANDERS, CALIFORNIA, EARTHQUAKE** *SCIENCE*
Hill, D. P., Reasenber, P. A., Michael, A., ARABAZ, W. J., Beroza, G., Brumbaugh, D., Brune, J. N., Castro, R., Davis, S., dePolo, D., ELLSWORTH, W. L., Gombert, J., Harmsen, et al
1993; 260 (5114): 1617-1623